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ABSTRACT

The Integrated Science-Mathematics Education Project (ISMEP) is an NSF-funded, interdisciplinary science/mathematics education program for preservice elementary school teachers which fosters an increase in scientific and mathematical literacy, improved attitudes toward science and mathematics, and enhancement of intellectual development on the part of classroom teachers and public school pupils. ISMEP courses blend scientific, mathematical, and educational components while providing classroom, laboratory, and practicum experiences relevant to elementary school programs. Although an overview of the project, organizational flow chart, checklists, brochures, and an evaluation report are included, the major portion of the document is devoted to the modules used in the program. Individual's modules contain objectives, instructional references and materials, procedures, and assessment criteria. Sources used in the modules include activities from the "Science Course Improvement Study" and "Science A Process Approach," and other elementary science and mathematics curriculum projects. (Author/DS)

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INTEGRATED SCIENCE-MATHEMATICS EDUCATION PROJECT
(ISMEP)

Set of Modules

Principal Investigator/Project Director

Gary W. Boggess

1981

SE 035 841

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SECTION I - BUDGET AND FISCAL REPORT - MISSING FROM DOCUMENT PRIOR TO ITS BEING SHIPPED TO EDRS FOR FILMING.

BEST COPY AVAILABLE.

AN OVERVIEW OF NSF-SER 76-14851 AND ITS IMPACT ON MURRAY STATE UNIVERSITY

Prior to submission of the ISMEP to the National Science Foundation, a writing team from Murray State University visited innovative programs for elementary teachers including those housed at St. Teresa College, Winona State, The University of Indiana, Purdue University, and Austin Peay State University. Each had desirable traits but none addressed the broader-spectrum of pre-service elementary education that we envisioned. Since our goal was to improve both competency and attitude in and toward science/mathematics teaching, it seemed logical (although formidable) to incorporate the science, mathematics, and methodological components with the ISMEP package. Such was our plan and so we have done. Perhaps the real value of the ISMEP to the broader educational community is its standing as proof that the three can delightfully function as a single entity. Professionals from the three disciplines support the program and believe in its educational value. In fact, one cannot detect whether the professor of biology is teaching content or methodology and if the traditional education professor is not really a "pro" at number theory. The meshing of content and learning strategy is exemplary. Such a freely integrated program cannot be developed within traditional administrative frameworks. The success of MSU's ISMEP lies in the fact that involved faculty have developed and administered the project. All teaching faculty have been directly involved in directional/programmatic decisions as well as in the day-to-day planning and execution of the ISMEP.

With the recent "institutionalization" of the ISMEP there arose a strong need to untie the integrated package set up for the four-semester sequence. This need was generated by students in our regular teacher education program lacking credits in specific courses of science, mathematics, or education. Our staff found the ISMEP so well integrated that it taxed our very best professors to sort out the parts and then computerize them for easy access according to conventional course outlines. Again, the uniqueness of the ISMEP was appreciated.

Murray State University furnished excellent facilities for project development. Since the ISMEP has been "institutionalized" we have rapidly outgrown the facilities--but that's another story.

A twenty-four station laboratory with gas, water, electricity, etc. was designated for the ISMEP. This laboratory was in a building separate from professional education, science, and mathematics. Territorial imperatives have been minimized throughout. The isolation of the laboratory strongly supports the individualized, self-paced, modularized nature of the ISMEP. A 26' x 40' departmental library was made available to the ISMEP due to campus centralization of library holdings. The library, an office area, and an adjacent classroom were designated for ISMEP usage.

The Science Mathematics Education Resource Center is at the heart of ISMEP. Popular alphabet series are included for use in the ISMEP as well as copies made available for loan to area teachers. Reading areas with books, periodicals, and study guides are available. Videotaping of peer-taught mods, viewing of internally and externally produced tapes, and performance of most non-laboratory based mods are done within the Resource

Center. Mod evaluations are also held within partially-isolated areas of the center. Our problem now is how to accommodate a six-fold increase in student population. A large assembly hall and several smaller classrooms within the same building are available to the ISMEP. Murray State leadership has certainly met or exceeded the pledge to provide adequate facilities for the project.

ISMEP founders aimed at evaluation in three areas; 1) significant changes in students' abilities as they relate to science and mathematics (i.e. content), 2) students' attitude toward science and mathematics, and 3) some indication of intellectual development. MSU's Dr. Bill Price provided initial direction for the evaluation process. Later, Dr. Jack D. Rose, Superintendent of Calloway County Schools, assisted with project evaluation. Dr. Jack Renner and team from the University of Oklahoma were the external evaluators. Their report is attached. Some problems were inherent in the evaluation. First, it was difficult to attain "clear" control/experimental groups as the ISMEP comprises a large portion of pre-service education courses. Some students majoring in special education were included along with the regular elementary education majors. A lack of similarity between experimental/control, although slight, may have altered our original experimental design. However, the most significant deterrent was the lack of proven instruments available to determine accurate measures of the desired parameters. In summary, the reader is advised to consider "perceived" accomplishments of the ISMEP in addition to Dr. Renner's evaluation report. There is strong sentiment among project directors, staff, past students, area teachers, regional public school administrators, and MSU administrators that the project goals are being realized. However, documentation is admittedly scarce. Again, all agree that graduates of the ISMEP tend to function far more capably in classroom science and mathematics instruction--as well as overall performance--than counterparts from the traditionally-strong Murray State program. Pardon the old adage but the proof of the pudding still seems to be in the eating thereof. Additional data are being collected as we continue to attempt to quantify student progress.

The ISMEP hosted some sixty area inservice teachers during Su 78 and Su 79. Institute participants completed compressed and only slightly modified versions of the pre-service semester offerings. Although quite intense, participant feedback was positive--in fact, glowing. In addition to completing some twenty individualized mods, these teachers attended mini-workshops conducted by specialists and then generated volumes of material for immediate use in their own classroom through a "make and take" module. Descriptions and feedback of the summer institutes are attached. A goal of NSF's Project Spread has been realized via the ISMEP.

ISMEP staff have visited school systems throughout MSU's service region. Inservice day presentations, talks to educational/social/business organizations, and press releases have assisted us in informing the populace about this unique NSF project. Reception has been encouraging from all components. Our first class of ISMEP students will enter next year's job market. Their entry should be considerably less painful than those traditionally prepared. ISMEP students gain field experience during their first semester by actually teaching in area schools. This component has synergistically supported pre and inservice thrusts of the ISMEP.

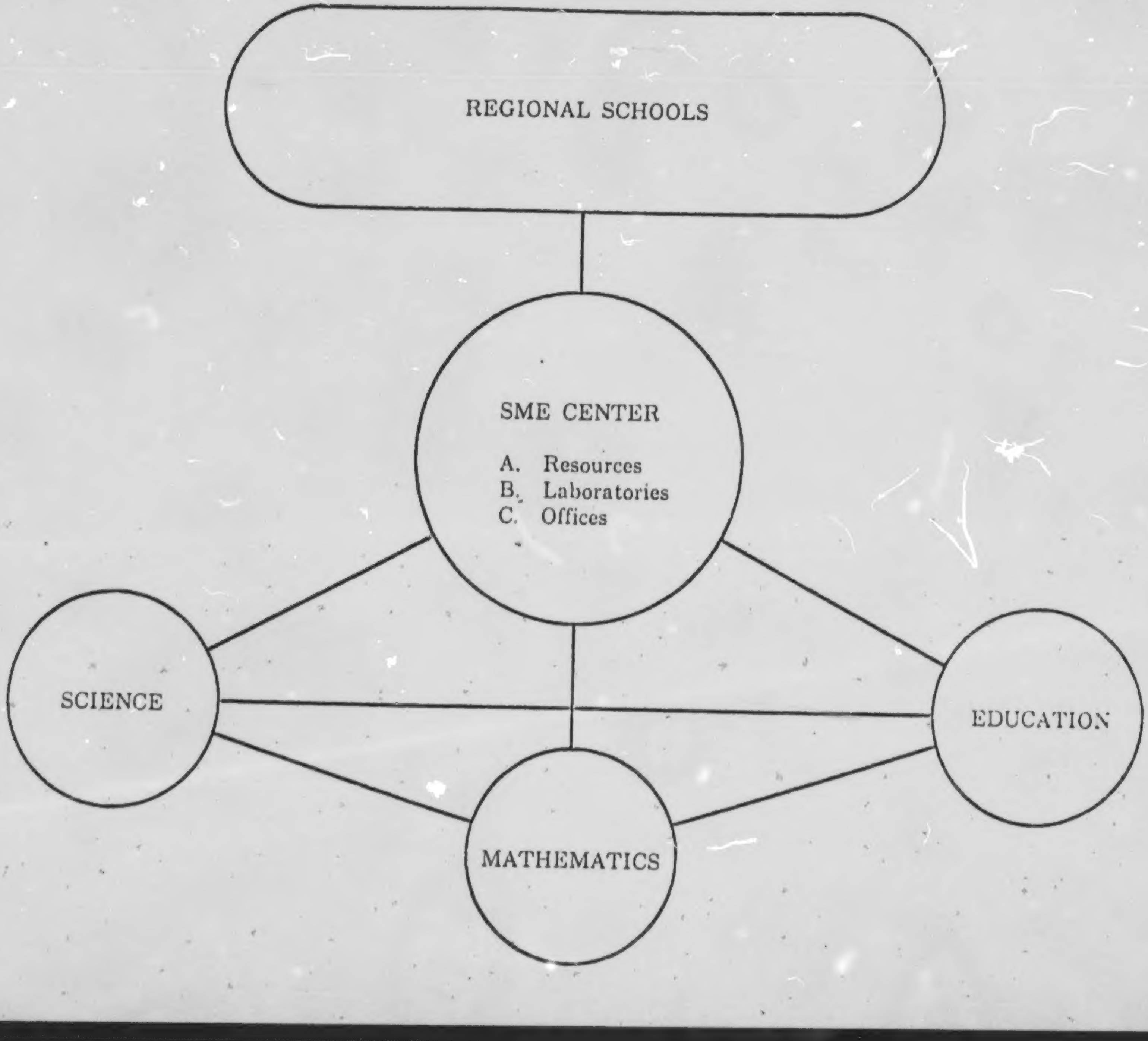
As earlier mentioned, the Resource Center provides materials and equipment--even a mini-computer--for loan to inservice teachers. These services have been provided without charge as part of our plan to enhance science/mathematics education throughout this region. In summary, the ISMEP has been and continues to be well-received by area teachers and administrators. Its impact is far-reaching on classroom activities.

A slight shift in emphasis resulted from the development and distribution of sophisticated, yet low-cost, mini-computers during the ISMEP grant period. An administrative decision was made to incorporate computer usage and a modicum of program development into the ISMEP. Such is clearly in line with project goals and objectives. Dr. Grady Cantrell, professor of mathematics, and Dr. Arvin Crafton, professor of professional studies, have combined their talents to generate programs for both instruction in and administration of the ISMEP. What might be perceived as a tangent to the original project may very well be its salvation through the "institutionalization" process. Sheer numbers of individual schedules, module selection and evaluation, student progress reports, and accounting details become unmanageable without either a large increase in staff or greater use of the computer. We have chosen the latter.

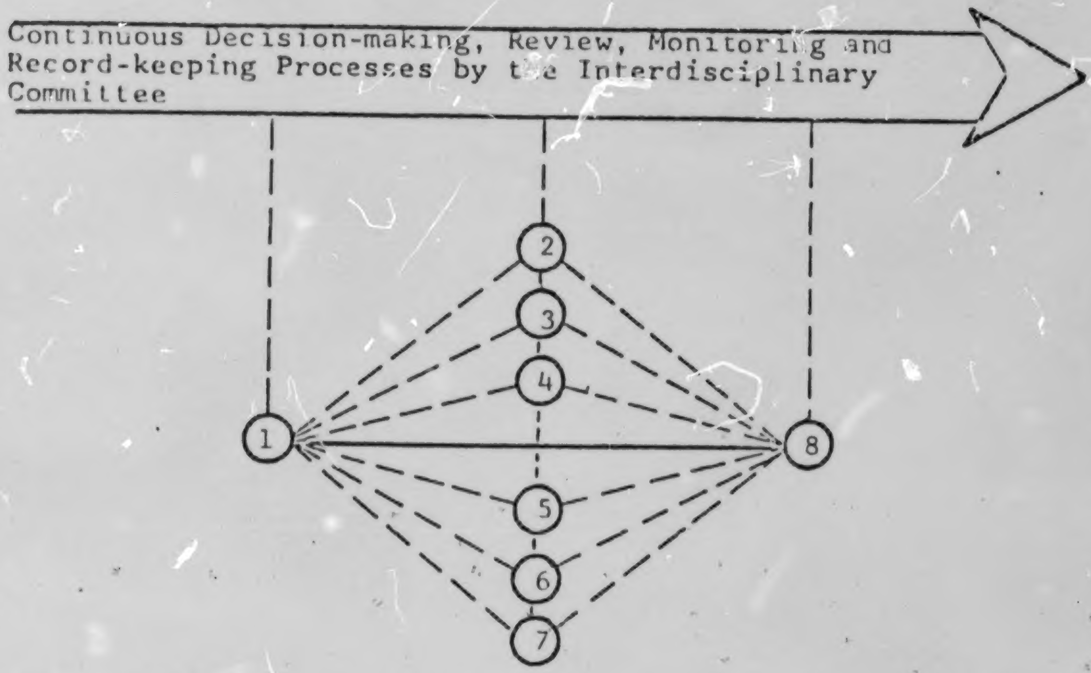
Another spin-off from the ISMEP is its inclusion as a basis for a doctoral dissertation. Mr. Bill Burnley is incorporating the ISMEP into his work at Arizona State University. Perhaps other research will be generated from this effort.

In conclusion, most of the goals and objectives of the ISMEP have been realized. Although desired gains in mathematical competency as measured by Dr. Renner are less than desirable, there are some quantitative data and a host of qualitative judgments that determine the project as quite successful. The greatest single measure may well be the faculty's decision to make the ISMEP the MSU curriculum for all of MSU's preservice elementary teachers.

SECTION III


REGIONAL SCHOOLS
SME CENTER
A. Resources
B. Laboratories
C. Offices
SCIENCE
EDUCATION
MATHEMATICS

STAGE I   SUMMER 1977


Continuous Decision-making, Review, Monitoring and Record-keeping Processes by the Interdisciplinary Committee
2
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*1. Preparatory activities

*2. Staff's detailed study of models

*3. Material and equipment preparation, etc.

*4. Initiate development of SMERC

*5. Inform regional schools and other interested persons and groups about the program

*6. Development of system for randomly selecting, informing and registering students

7. Initiate development of initial assessment activities

   *A. Involve external evaluators to prepare pretest materials and procedures for measurements related to intellectual development

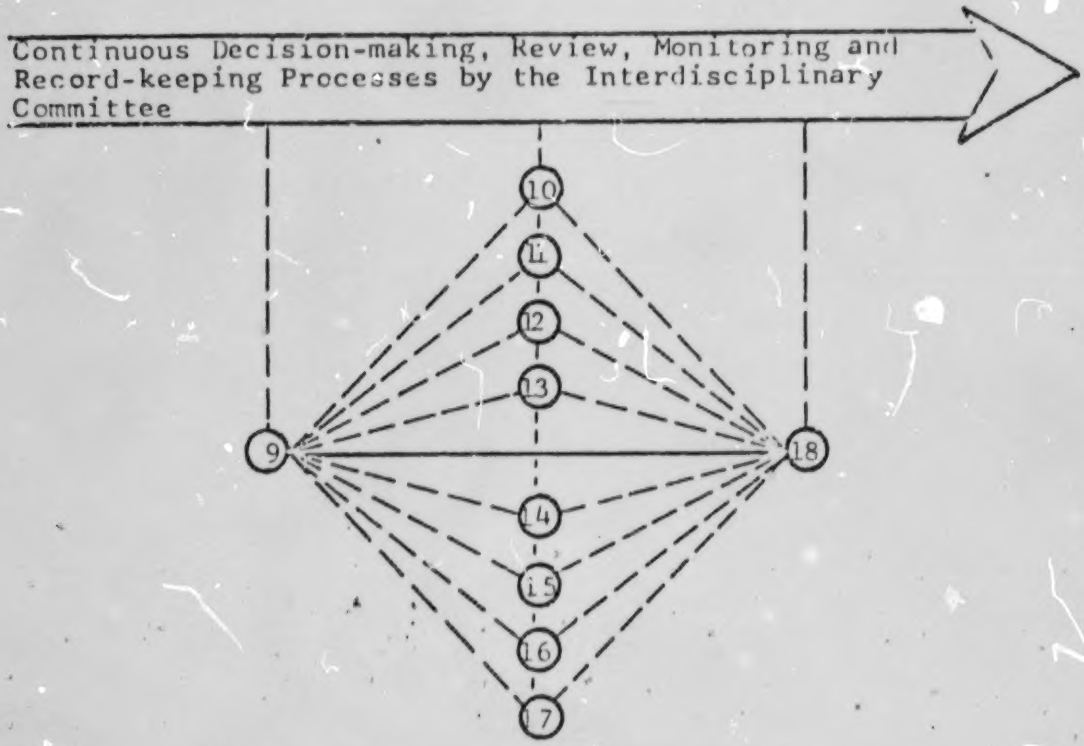
   *B. Involve the individual responsible for assessing achievement gains to assure pretest materials and procedures will be ready

   C. Development of instrument for measurement of attitude toward science and mathematics teaching -- somewhat weak

*8. Final considerations prior to 1977 Fall initiation of new undergraduate program

*complete as written

STAGE II ACADEMIC YEAR 1977-78


Continuous Decision-making, Review, Monitoring and Record-keeping Processes by the Interdisciplinary Committee
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* 9. Actual start-up of new program and SMERC

*10. Randomly assign students to either the experimental or control groups

11. Pretest both the experimental and contral groups on all three identifi
areas A. Intellectual development B. Achievement C. Affective doma
(somewhat weak here)

*12. Begin instruction with MMP and US I modules

*13. Ongoing planning and reviewing, and development of proper cross-links
participating faculty

*14. Continued development of SMERC based on perceived needs

*15. Involve regional teachers through in-service type arrangements

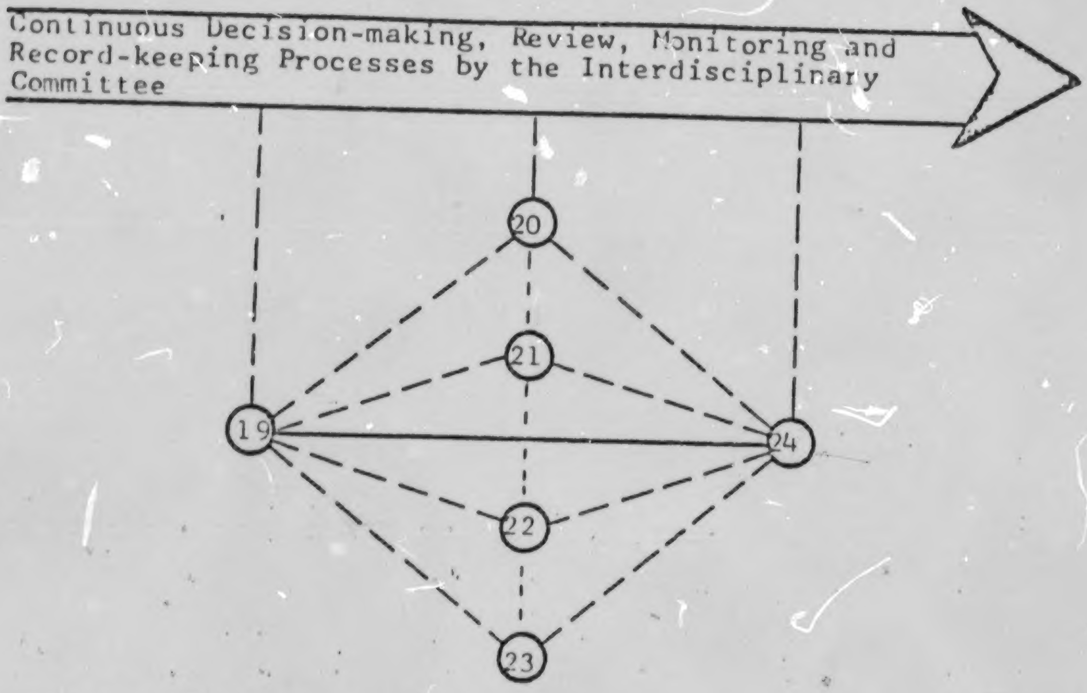
*16. Publicize program, activities, and SMERC

*17. Posttest both the experimental and control groups at the completion of the first year on all three identified areas (Renner)

*18. Recommendations related to continuance and change.

*complete as written

STAGE III SUMMER 1978


Continuous Decision-making, Review, Monitoring and Record-keeping Processes by the Interdisciplinary Committee
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23

*19. Review recommendations and involve regional teachers

*20. Review and study recommendations of the committee and participating faculty from the first year

*21. Review and study test results from first year

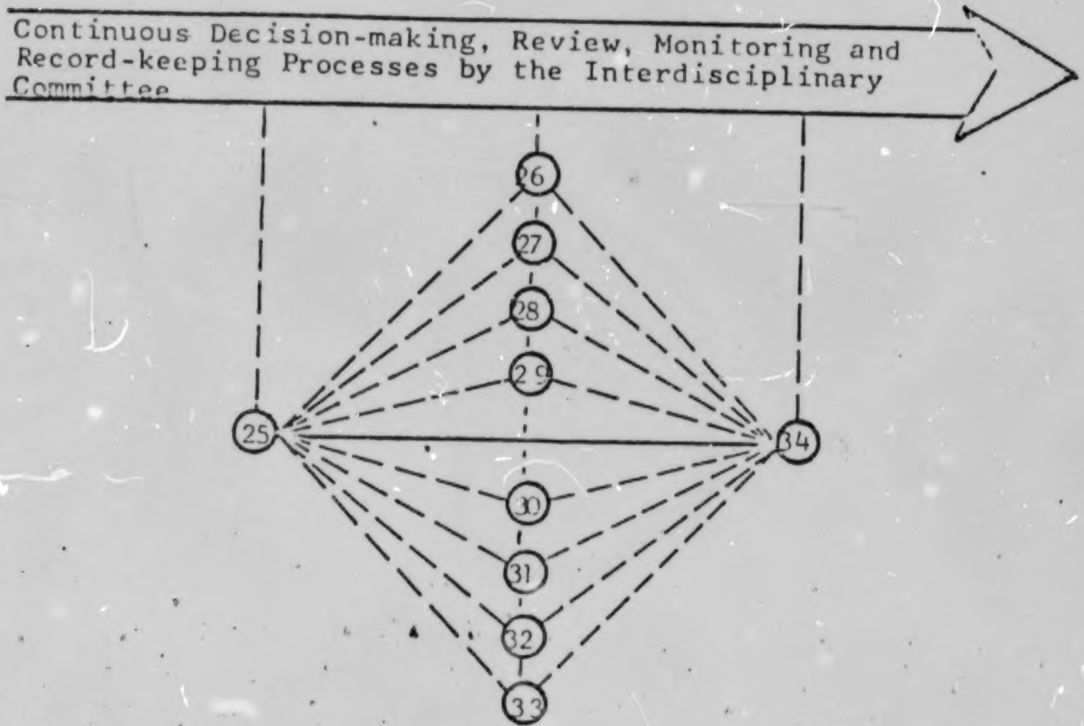
*22. Provide three-week institute for 30 regional teachers (tremendously successful)

*23. Continued development of SMERC

*24. Final considerations prior to initiating the second year of the new program

*completed as written

STAGE IV ACADEMIC YEAR 1978-79


Continuous Decision-making, Review, Monitoring and Record-keeping Processes by the Interdisciplinary Committee
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5. Start-up of second year of program

6. Begin second year of instruction in the new program utilizing MSU mods

7. Programs designed to cause greater utilization of SMERC by regional teacher

8. Continued development of SMERC based on perceived needs

9. Encourage representatives from other colleges and universities to visit and observe the program and SMERC

0. On-going planning and reviewing, and development of proper cross-links by participating faculty (strong here)

1. Dissemination through conference, publications, etc. (KY Acad. Sci.)

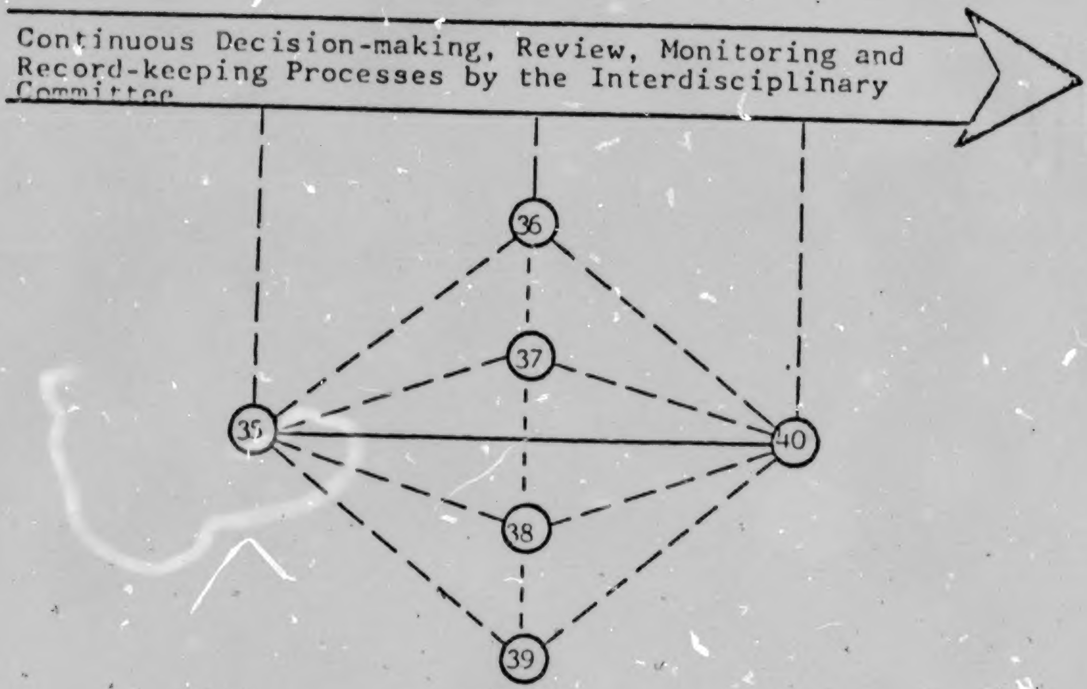
2. Plans revised for complete transfer from NSF and MSU support to total MSU support

3. Posttest on all three identified areas, students in both the experimental and control groups who have completed two years of the program (Renner)

4. Recommendations related to continuance and change

*completed as written

STACE V SUMMER 1979


Continuous Decision-making, Review, Monitoring and Record-keeping Processes by the Interdisciplinary Committee
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*35. Review and dissemination

*36. In-service programs for 30 regional teachers and in depth presentation of program to 15 representatives from other colleges and universities

*37. Dissemination through conferences, publications, etc. (local workshops with Postlethwait, Karplus, Bork et al)

*38. Intensive analysis of all assessments with resulting recommendations concerning the direction of the program and SMERC

*39. Finalized plans for complete transfer from NSF and MSU support to total MSU support

*40. Final decisions

*completed as written

TRADITIONAL AND ISMEP PROGRAMS FOR THE SCIENCE-MATHEMATICS EDUCATION CURRICULUM FOR ELEMENTARY EDUCATION MAJORS @ MURRAY STATE UNIVERSITY

Traditional Program

		Credit Hours
Mathematics 115	- Fundamental Concepts I	3
Mathematics 315	- Fundamental Concepts II	3
Ele. Educ. 201	- Teaching of Mathematics	3
Biology 101	- General Biology	4
Physical Sci.	- (several choices)	4
Science Elective	- (several choices)	4
Ele. Educ. 502	- Teaching of Science	3
Required		24
Ele. Edu. 508	- Teaching Modern Math. (encouraged elective)	3
Total		27

ISMEP Program

	Credit Hours
SME 100	6
SME 150	6
SME 200	6
SME 250	6
Required	24
Encouraged Elective	3
Total	27

A list of mods is attached.

Gary Boggess, Director
mer Institute in SME for
Elementary Teachers
311 Mason Hall
Murray State University
Murray, KY 42071

To:

Science—Mathematics—Education
Resource Center

Murray State University
Murray, Kentucky

Announces

1978 SUMMER INSTITUTE
in
INTEGRATED SCIENCE–MATHEMATICS–EDUCATION
for
ELEMENTARY TEACHERS

June 13 - June 29
Sponsored by the National Science Foundation

Purpose

The institute is designed to provide the opportunity for in-service elementary teachers to increase their knowledge of recent curriculum developments and materials in science and mathematics and to improve their skills in the use of these materials for effective inquiry teaching.

It will also serve a secondary purpose by making area teachers aware of resources available for their use from the SME Resource Center and the opportunity to select and prepare some materials for use in their own classrooms.

Participants

Thirty elementary teachers will be selected from counties within 100 miles of Murray State University to participate in the institute.

To be eligible for consideration an applicant must have taught at least one year and be a teacher or administrator in an elementary school.

The staff will select participants giving consideration to length of time before retirement, background in science and mathematics education and geographical distribution.

All participants must be accepted for admission to Murray State University. Application forms for admission to Murray State University may be obtained from the Dean of Admissions at Murray State University.

Program

The institute will coincide with the first 13 days of the regular summer session at the University, beginning June 13, 1978 and ending June 29, 1978. The institute will provide three credit hours of graduate credit (SME 600), Advanced Integrated-Science-Math-Education for Elementary Teachers which may be applied toward graduate programs where appropriate.

The core of the institute will involve the selection and completion of instructional modules (MODs) in science, mathematics and/or methodology utilizing philosophy and materials from the ESS, SAPA, SCIS science programs and the MMP math program. Some MODs will be required and others may be selected according to the interest and needs of the individual. Objectives are formulated in behavioral terms and assessments will be based on fulfilling these objectives. Most evaluations will be oral. Creative components are built into many of the MODs and are designed to assist participants in developing the types of creativity needed for effective inquiry teaching.

Group sessions will be scheduled for some of the mornings with the laboratory and resource center available during afternoons and evenings for individual and group activities and the preparation of instructional materials.

Benefits

Each participant who successfully completes the institute will receive 3 hours graduate credit (tuition free) in SME 600, Advanced Integrated-Science-Math-Education for Elementary Teachers. This credit may be applied toward advanced programs where applicable. Materials will be provided by the institute and each participant will receive a $100 stipend to help defray cost of travel and subsistence while participating in the institute.

Staff

The instructional staff of the institute is tentatively as follows:

B. E. Burnley, M.S., 1966 Ph. D. Candidate, Arizona State University. Assistant Professor of Astronomy.

Arvin Crafton, Ed. D., 1966, University of Georgia. Associate Professor in Department of Professional Studies.

Robert Johnson, Ph. D., 1969, West Virginia University. Professor of Biology.

Christine Parker, E.D., 1974, Auburn University. Associate Professor of Mathematics.

Facilities

The institute will be conducted in the ISMEP Center in Mason Hall. The Center consists of a resource room, a classroom, and a well-equipped laboratory. The resource room contains complete sets of materials to accompany the SAPA, SCIS, and ESS elementary science programs, many mathematics manipulates, games, selected films, videotapes, books, and other selected materials. Modern audio-visual materials are also available.

Administration

The Director of the Institute will be Dr. Gary Boggess, Dean of the College of Environmental Sciences. For application blanks, complete the tear-off section and mail to:

Dr. Gary Boggess
Summer Institute in SME for
Elementary Teachers
311 Mason Hall
Murray State University
Murray, KY 42071

Phone: (502) 762-2718

Requests for application blanks should be mailed **as soon as possible.** Completed application blanks must be postmarked by **March 15, 1978** to guarantee that they will be considered.

Invitations to participate will be issued by **April 15, 1978,** and notification of acceptance must be received by **May 1, 1978.**

Dear Dr. Boggess:

I am interested in participating in the 1978 Summer Institute in Integrated Science-Mathematics-Education for Elementary Teachers. Please rush application forms to the address below.

name ____________________

address ____________________

____

____

In the operations of this project and in selection of individuals for participation in, and administration of this project, Murray State University will not discriminate against any person on the grounds of race, creed, color, sex, age, or national origin.

Dr. Gary Boggess, Director
Summer Institute in SME for
Elementary Teachers
311 Mason Hall
Murray State University
Murray, KY 42071

To:

Science—Mathematics—Education
Resource Center

Murray State University
Murray, Kentucky

Announces
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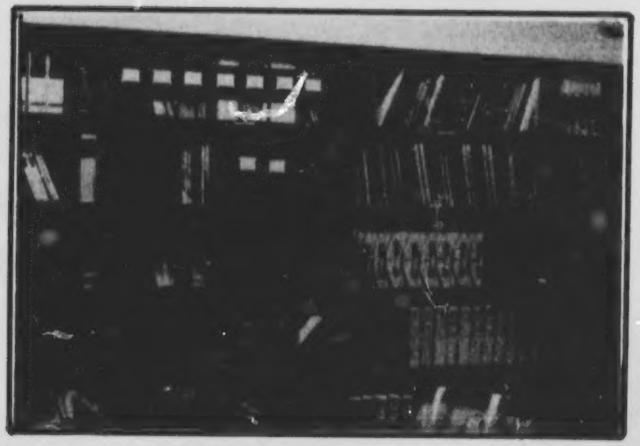
ELEMENTARY TEACHERS

June 13-June 29, 1979

Sponsored by the National Science Foundation



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Group sessions will be scheduled for some of the mornings with the laboratory and resource center available during afternoons and evenings for individual and group activities and the preparation of instructional materials.

Since the institute is a laboratory-oriented program, it will not be practical to enroll for other college work during the time of the institute.

Benefits

Each participant who successfully completes the institute will receive 3 hours graduate credit (tuition free) in SME 600, Advanced Integrated-Science-Math-Education for Elementary Teachers. This credit may be applied toward advanced programs where applicable. Materials will be provided by the institute and each participant will receive a $100 stipend to help defray cost of travel and subsistence while participating in the institute.

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B. E. Burnley, M.S., 1966, Ph.D. Candidate, Arizona State University. Assistant Professor of Astronomy.

Arvin Crafton, Ed.D., 1966, University of Georgia. Associate Professor in Department of Professional Studies.

Harold Eversmeyer, Ph.D., 1965, Kansas State University. Professor of Biology.

Grady Cantrell, Ph.D., 1968, University of Kentucky. Associate Professor of Mathematics.

Facilities

The institute will be conducted in the ISMEP Center in Mason Hall. The Center consists of a resource room, a classroom, and a well-equipped laboratory. The resource room contains complete sets of materials to accompany the SAPA, SCIS, and ESS elementary science programs, many mathematics manipulatives, games, selected films, videotapes, books, and other selected materials. Modern audio-visual materials are also available.

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SECTION VI

PURPOSE

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It will also serve a secondary purpose by making area teachers aware of resources available for their use from the SME Resource Center and the opportunity to select and prepare some materials for use in their own classrooms.

- -

Considering the objectives (purpose) of SI '78, please candidly and anonymously complete the following evaluation.

Participant Evaluation of SI '78

	Outstanding	Excellent	Good	Average	Poor
1. Faculty					
a) Interest in and dedication to	31				
b) Helpfulness (including willingness to let participants discover)	31				

Please Comment:

	Outstanding	Excellent	Good	Average	Poor
2. Materials					
a) Availability	27	4			
b) Utility in the course, SME 600	25	6			
c) Applicability in your own teaching	21	9			

Suggestions:

	Outstanding	Excellent	Good	Average	Poor
3. Facilities					
a) Resource Center	31				
b) Laboratory	27	2			
c) Management of facilities	29	2			

Suggestions:

	Outstanding	Excellent	Good	Average	Poor
4. Program					
a) The MOD approach	24	7			
b) Relevance of Mods	24	7			
c) Quality of Mods	24	7			
d) Evaluation of Mods	23	8			
e) Outside speakers	10	20	1		

Comments:

Please write comments on the following:

5. Effort and Reward

   a) Time involved

   b) Apparent rewards reaped

   Comments:

6. Projections/Suggestions

   a) How SME 600 will assist you in your teaching

   b) For a follow-up throughout '78-'79

   c) Utility of ISMEP's Resource Center throughout the region

   d) Specific changes for next summer's program (SI '79)

   e) Other

7. What were the "highlights" of SI '78 for you?

8. In an attempt to evaluate your reception of, interest in, and utilization of SME 600 MODs, please complete this attempt at measuring competency and relevancy.

Please express the degree to which you feel:

competent to return to your local situation and explain each of the ideas to your fellow faculty.

the importance that you feel should be placed on each item in your total program.

Respond with the following guidelines in mind:

Competence		Importance	
4.	feel quite competent; will be able to help others understand this idea	4.	very important, vital to an effective classroom program
3.	feel moderately competent	3.	of moderate importance
2.	unsure about competency	2.	unsure about importance
1.	do not feel competent enough to help others	1.	not at all important to an effective classroom program

Please circle your response:

MODs	Competence				Importance				Recommended for SI '79		
	4	3	2	1	4	3	2	1	YES	NO	MAYBE
600-Seminar on Self Concept (Dr. Lewis Bossing)	9	20	1		21	9			22	1	6
601-Introduction to Inquiry Program in Science & Math (Dr. Ertle Thompson)	7	17	4	2	8	14	7	1	18	2	8
602-Comprehensive School Mathematics Program I(Dr. Ron Ward & Clare Heidema)	11	14	7		10	15	5	1	21	1	7
603-Material Objects	23	6	1		21	9			27		2
604-Interpolating & Extrapolating in Terms of Three Simple Physical Systems	14	15	4		16	14	3		27		5
605-Seminar & Exercises in Numeration	15	17			26	10			30		1
606-Controlling Variables	17	13	1		22	8			30		
607-Inquiry Teaching Strategies (Father Stanley Bezuszka)	13	13	4		11	14	3	2	24	2	6
608-Newton's Laws	14	15	2		21	10	1		28		2
609-Seminar & Exercises in Rational Numbers	21	9	2		23	7	1		27		1

8. (Continued)

MODs	Competence				Importance				Recommended for SI '79		
	4	3	2	1	4	3	2	1	YES	NO	MAYBE
610-Characteristics of Living Things	10	18	3		14	11	12		29		1
611-Heat Transfer	20	10	1		20	10	1		28	1	1
612-Preparation for Video Lesson	14	13	3		13	13	6	1	20	3	8
613-Videotaping & Reviewing Lesson	14	14	3		13	12	7		20	3	8
614-Life Cycles	5	3	2		6	4			9	1	
615-Float or Sink?	19	6	1		24	2			26		
616-Comprehensive School Mathematics Program II (Dr. Ron Ward & Clare Heidema)	9	11	7		11	5	9	1	14	4	7
617-Communities	3	1			2	2			4		
618-Make and Take	25	1			24	2			25		
619-Analysis of Mixtures	3	3			3	2	1		4		2
620-Number Theory	2	4	2		3	4	1		7		
621-Cell Division & Growth	3	4	2		5	3	1		7		1
622-Graphing	2	3	1		3	3			4		1
623-The Cycle of th[illegible]oon		1	2		1	2			2		
624-Metric Measurement	17	5			20	2			22		
625-Brine Shrimp	3	2	1		5		1		5		
626-Teaching Geometry to Elementary Children	21	5			24	2			25		
627-Soaps and Detergents	12	8	1		13	7	2		19		3

MOD 100 Introduction to SAPA, SCIS, and ESS

OBJECTIVE:

After viewing the filmstrips and studying the accompanying pamphlets, you will be able to answer the questions listed on the attached sheet.

ACTIVITIES:

1. View "Introduction," ESS, SCIS, SAPA filmstrip programs.
2. Read the accompanying pamphlets for the filmstrip programs.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Far West Laboratory for Educational Research & Development, Elementary Science Information Unit, filmstrip and cassette on "Introduction," ESS, SCIS, and SAPA.
2. 35 mm filmstrip projector
3. Cassette recorder

FINAL ASSESSMENT:

You will draw two numbers at random that correspond to items on the attached list and discuss those items with an instructor. You may use notes.

ASSESSMENT ITEMS PERTAINING TO ESS, SAPA, AND SCIS:

1. List at least three similarities of the three programs.
2. What importance is reading (by children) given in all three programs?
3. What is meant by the term "process" in the context of "Science - A Process Approach?"
4. Discuss the goals of the three programs.
5. List at least three topics from each of the programs and give a brief description of each.
6. Discuss the evaluation procedures of each of the three programs.
7. Discuss the unit sequencing in all three programs.
8. State which one of the three programs you think is the most structured and explain your answer.
9. Discuss the learning cycle presented by SCIS.
10. How do the planners of SCIS and ESS differ in their approach to the use of "scientific" terminology?
11. How is Piagetian philosophy incorporated into the SCIS curriculum?

MOD 102 Observing (Group Activity) (SAPA)
Using simple material objects in order to distinguish between observing and inferring

OBSERVING

"Observations are basic to any scientific investigation. These observations in turn lead to the construction of inferences that can be tested by further observation. Therefore, observing provides both a basis for constructing inferences and for testing existing inferences. In SAPA, observations are statements of properties that can be perceived by use of the senses." SAPA, Guide for Inservice Instruction, p. 11.

OBJECTIVES:

At the conclusion of this group session, you should be able to:

1. identify and name properties of an object or situation by using at least four senses;
2. distinguish between observations and inferences;
3. state the observations in quantitative terms whenever possible;
4. describe observable changes of properties of an object or a system;
5. describe an object so another person can identify the object in a set of similar objects.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, Guide for Inservice Instruction, pp. 1 - 3,
2. See reference above for materials and procedure.

FINAL ASSESSMENT:

See objectives above.

(Students receive this sheet after the group activity so their observations are not biased and so they have a record of the activity.)

Pretend that you do not know that the item in front of you is. To indicate this, call it the object. List as many observable properties of the object as you can. Use any of the other items to help you make your observations. Be sure to make your list before reading on.

Now review your observations. Here are some questions to use as you check your list.

1. How many of your senses did you use?
2. Did you include any quantitative observations? For example, did you measure the size or weight of the object?
3. Did you list any observations that involved a change? Did you use the water or the match to change the properties of the object?
4. Did you include any inferences in your list of observations? For example, did you say that the object was a sugar cube? If you said it was a sugar cube, ask yourself if a sugar cube is a property you can actually observe with your senses. If you hadn't known that the object was a sugar cube, would you have known for sure that the object wasn't something else, like a herbicide, a fertilizer, or even a poison disguised to look like a sugar cube?

After thinking about these questions, add to your list of observations and delete any statements which appear to be inferences rather than observations. The following activity will provide you with some guidelines that should enable you to make more complete and accurate observations.

MOD 103 Numeration

This MOD is designed to provide you with insight and perspective into difficulties encountered in understanding our numeration system.

OBJECTIVES:

After completing this MOD you will be able to:

1. Distinguish a number and a numeral.
2. Understand and name some properties of various numeration systems.
3. Discuss the importance of properties that are inherent in our numeration system.
4. Understand and use the concepts of grouping, trading, and place value in the number system with any base.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Numeration
2. Multibase arithmetic blocks
3. Colored chips
4. Abacus
5. Two or three dice

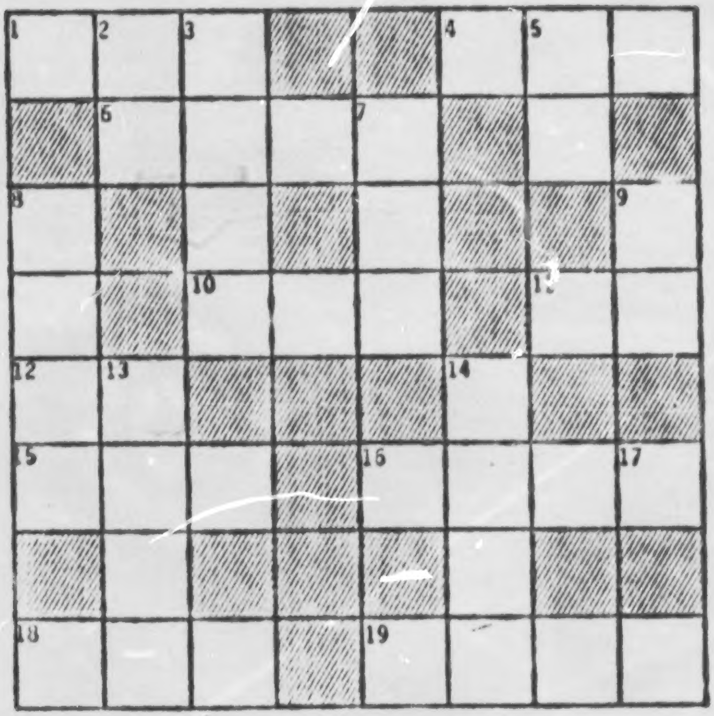
PROCEDURE:

1. In MMP, Numeration, do Activities 1, 2, 4, and 5. Do not write in books.
2. Prepare a game to be used in connection with grouping for your permanent file.

FINAL ASSESSMENT:

1. Bring your response sheets and game to the evaluation.
2. Be prepared to answer questions on all points in objectives.

CROSS-NUMBER PUZZLE


1
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ACROSS

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MOD 104 Material Objects (SCIS)
Observing, classifying

PREREQUISITE: Read SCIS, Material Objects, Teacher's Guide, "The SCIS Conceptual Framework," "Program Overview," and "Clues for the Teacher," pp. 8-17.

OBJECTIVES:

1. At the completion of this MOD, you will be familiar with the SCIS philosophy and the materials and references of SCIS, Material Objects.
2. Given a rock and a definition of the word "property," you will be able to list at least 5 properties of that rock.
3. Given five wooden blocks, you will classify them into a classification scheme.
4. Given four metal pieces, you will classify them into a classification scheme.
5. Given vials or sawdust and woodshavings, you will match the dust and shavings to blocks of similar wood.
6. Given 5 different liquids, you will list at least 5 properties of each and in addition list at least 3 properties of any combination of the 5 liquids.
7. Given certain types of gases, you will observe and identify properties of those gases.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Material Objects, Teacher's Guide
2. Materials from a commercial kit of Material Objects

FINAL ASSESSMENT:

1. See objectives above.
2. Each activity identifies further tasks to be performed and the materials to be kept for the final assessment.

PROCEDURE:

These activities refer to SCIS, Material Objects, Teacher's Guide.

1. Read "Objects in the Classroom," pp. 24-25. Be able to discuss the meaning of the word "property."

2. List at least five properties of a rock selected from the box of 200 assorted rocks. The instructor will try to identify your rock in the collection from your set of properties. Your ability to perceive "property" will be determined on this basis.

3. Take five numbered wooden blocks; classify them by the scheme in the Teacher's Guide, p. 43. Identify them as oak, walnut, pine, balsa or mahagony. For the final assessment bring to your instructor your classification chart and your selection of blocks used in the exercise.

4. Take four metal pieces and classify them according to the scheme presented in the Teacher's Guide, p. 43. At the time of your final assessment bring to your instructor your classification chart and your selection of metal pieces.

5. The objective of this activity is to match the vials of wood dust and wood that you have classified and identified. In the MOD tray, find 6 vials of wood dust and shavings. These are labeled 1 through 6.

   You may conduct tests on the smaller blocks but not on the larger blocks. Fill in the chart below and present it to the instructor at the final assessment.

Vial	Type of Wood
1	
2	
3	
4	
5	
6	

6. Describe the properties of five different liquids and describe various combinations of liquids.
List at least 5 properties of each labeled container of liquid. Please use fluids sparingly.

Liquid A Properties

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Liquid B Properties

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Liquid C Properties

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Liquid D Properties

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Liquid E Properties

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

Proceed by mixing any combination of two or more liquids in a separate vial. Describe the properties of your new liquid. Bring this vial of mixed liquid to your instructor at the time of final assessment.

Properties of new liquid mixed from liquids labeled ___ ___ ___

1. ____________________

2. ____________________

3. ____________________

4. ____________________

If necessary, describe more completely on the back of this sheet.

If the properties of your new liquid change after 5 minutes, 1 hour, or 24 hours, describe how they change on the back of this page.

7. Read "Observing Gases," pp. 58-59 and perform the experiments. Record your data on the back of this page. Bring your data to the instructor. You will find Freon-12, balloons, iodine crystals, and balloon pump in the MOD tray. Please read the precautions concerning iodine and Freon in the SCIS, Teacher's Guide, p. 58.

MOD 105 Numeration in the Elementary School

This MOD will provide an opportunity for a general overview of the scope and sequence of numeration topics in the elementary school and some hands-on experience with grouping and place value aids.

OBJECTIVES:

At the end of this MOD you will be able to:

1. Arrange an appropriate sequence for numeration activities for elementary school children.
2. Be familiar with grade level of various numeration topics for elementary school students.
3. Select appropriate hands-on aids for different numeration concepts.
4. Extend numeration concepts to decimals.
5. Apply use of exponents in writing numbers in scientific notation.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Numeration
2. MMP Slide-tape, "Numeration in the Elementary School"
3. Abacus, colored chips, Dienes blocks, bundling sticks, unifix cubes, place value charts
4. Construction paper, scissors, ruler, glue, centimeter grid paper, felt-tip pens
5. Elementary school mathematics textbook series, found in Resource Center

PROCEDURE:

1. View the MMP slide-tape, "Numeration in the Elementary School."
2. In MMP, Numeration, do Activity 7, parts 2 and 3b, Activities 8, 11, 12 and 13.

FINAL ASSESSMENT:

1. Bring all work sheets and completed projects to the evaluation.
2. Be able to respond to all objectives above.
3. Prepare for a brief written exercise on scientific notation.

MOD 10 6 Classifying (SAPA)
Punch Cards

CLASSIFYING

"There are many ways to construct classification systems. In SAPA, one, two or multi-stage classification systems are emphasized. In these systems, each stage divides objects to be sorted into 'those that possess a certain observable property' and 'those that do not possess this observable property'." SAPA, Guide for Inservice Instruction, p. 102

OBJECTIVES:

1. Given a set of 8 objects whose numbers you have drawn from a list of 20 objects, you will write a classification key in the presence of the instructor. The key should enable anyone ignorant of the names of the objects to identify exactly each one.
2. Using the classification key you made for a set of 10 or more objects which you have chosen (not from the MOD tray), you will code the classification into a simple punch card system.
3. Given the set of punch cards you made to classify the objects above in 2, you will use your punch card system to identify the objects selected by the instructor.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Collection of 20 objects available in laboratory
2. Set of 10 or more objects provided by student
3. SAPA, 56, Punch Cards
4. SAPA, 67, Identifying Materials
5. Stiff paper cards of uniform size
6. Paper punch
7. Small metal rod

FINAL ASSESSMENT:

1. See objectives above.
2. For assessment of objectives 2 and 3, bring the real objects that you used to the instructor.

(This MOD may be introduced in a brief meeting of the entire class. Page 4 of this MOD may be used to facilitate the introductory discussion.)

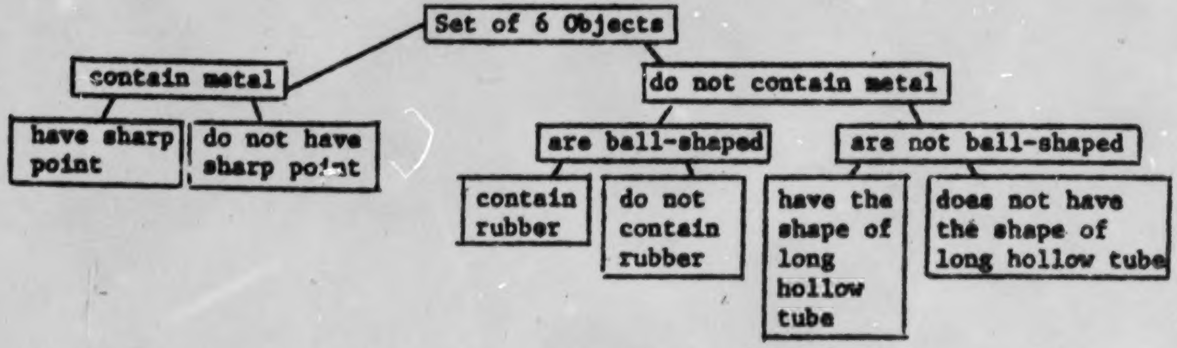
PROCEDURE:

A classification key or a taxonomic key is a printed device which allows an inexperienced observer to identify an unknown object. In the construction of such a key for a set of objects, the problem is to differentiate between objects in an efficient way.

Given the following set of objects:

> Tennis ball, ping-pong ball, thumbtack, plastic ruler, metal spoon, drinking straw

your objective is to enable a hypothetical person who would not know any of these things to pick them out of the set. First, divide the objects into two mutually exclusive groups, for example, those that contain metal and those that do not. Then divide each of these subgroups again into two mutually exclusive groups. The non-metallic objects could be divided into those that are ball-shaped and those that are not. The following key is the outcome of such divisions:


Set of 6 Objects
contain metal
do not contain metal
have sharp point
do not have sharp point
are ball-shaped
are not ball-shaped
contain rubber
do not contain rubber
have the shape of long hollow tube
does not have the shape of long hollow tube

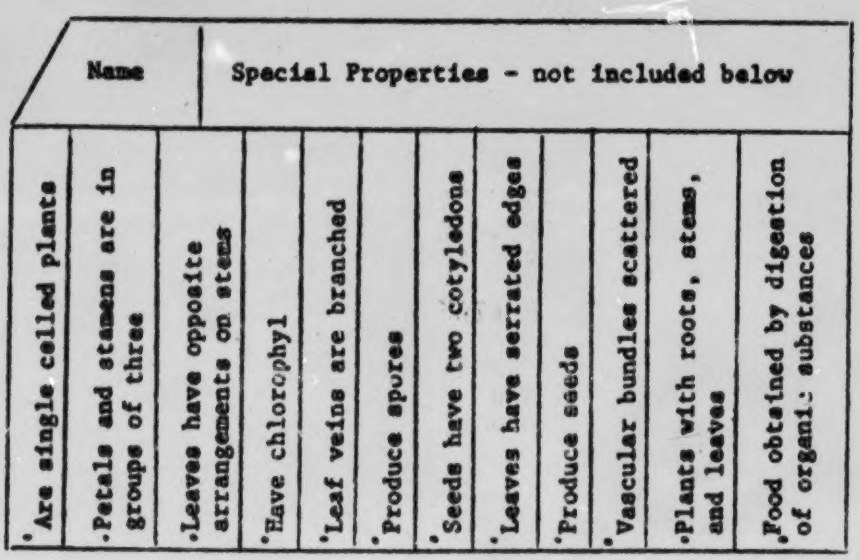
An observer who does not know any of the six objects can pick any one of them and, by comparing its properties against the descriptions in the key, can correctly classify it.

Suggested activity: Set up a classification key for a group of 6 to 8 people that would enable a stranger to your group to identify any member.

You have learned from the above activity to set up classification schemes for sets of objects - schemes based on mutually exclusive properties of those objects. The following explanation should help you to be able to set up a punch card system which codes a classification in an orderly way.

Collect 10 or more real objects to classify and make a card for each object. The cards should be rather stiff and uniform in size such as 3" x 5" or 4" x 6" note cards. Divide each card into sections to include the number of properties used in your classification. At the top leave two extra sections for the name of the object and for special properties.

Cut the same corner off each card. Approximately ¼ inch from the edge of each card make a row of punches, one punch in each section, except for the top sections with the name of the object and the special properties. Your cards will look like this:



Name	Special Properties - not included below										
Are single celled plants	Petals and stamens are in groups of three	Leaves have opposite arrangements on stems	Have chlorophyl	Leaf veins are branched	Produce spores	Seeds have two cotyledons	Leaves have serrated edges	Produce seeds	Vascular bundles scattered	Plants with roots, stems, and leaves	Food obtained by digestion of organic substances

If necessary, the ends and both sides of the card may be used.

Now code the cards. Take the first card and write in the name of the object. Then, in each section, indicate whether the object has the characteristic or property designated by that section. Every answer must be "yes" or "no." To indicate a "yes" answer, cut a V from the edge of the card into the punch hole. To indicate a "no" answer, leave the section as it is. Note how this relates to the selection of mutually exclusive categories in the previous exercise. If an object has a special property not set up as a section, write it in the space for special properties. After cards have been made for all the objects, they can be sorted by using a pin or small metal rod. Small knitting needles work well.

To identify an unknown, slide the sorter through the hole which corresponds to a certain property in the unknown. Gently shake the cards and lift the sorter. The cards which fall out of the deck represent objects that have the property in question. Set aside the cards that remain on the sorter. Use the stack of cards that drop, select another property and sort. Now you know that the cards that fall out have the first and second property. Repeat the sorting process, using properties of the unknown object until only one card remains. If more than one card remains, write the special properties on the cards giving another means of distinguishing between objects.

Be prepared to demonstrate how your system works for any individual object the instructor may select from your collection.

Name	**Special Properties**
	____________________
	____________________

Height = 5'3" or over	Currently wearing a ring on the ring finger of either hand	Shoe size 7½ or above	Left-handed	Presently wearing blue jeans	Natural hair color (no lying)	Wear contact lenses	Weight = 115 lbs. or over

Take the SAPA Module 67 cards (5" x 8") in the MOD tray and follow the instructions. When you finish completely the sorting instructions, put the card labeled start here back on top of the deck. The order of the other cards is unimportant.

MOD 107 Teaching Children: Numeration Concepts

PREREQUISITE: MOD 103, 105

OBJECTIVE:

After viewing the video program of "model" teaching your ISMEP-partner and you will plan and teach to four or five children appropriate concepts and skills on numeration.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Indiana Model Teaching Video Programs on Numeration
2. Elementary mathematics textbooks
3. MMP, Numeration, Activities 15 and 16
4. Video-tape recorder
5. TV monitor

FINAL ASSESSMENT:

Your plan will be discussed with and approved by your instructor(s) prior to the actual teaching experience. Shortly following the actual teaching a 30-minute time period will be scheduled with your instructor(s) to discuss and evaluate the experience. Input from the classroom teacher will be sought and utilized to the extent possible.

EXAMPLES OF BEHAVORIAL OBJECTIVES

A SEQUENCE OF OBJECTIVES
FOR DEVELOPING THE MULTIPLICATION ALGORITHM

1. The child will be able to state the products for all multiplication combinations through 9 x 9.
2. The child will be able to find the product when a multiple of ten is multiplied by a single-digit number.
3. The child will be able to find the product when any two-digit number is multiplied by a single-digit number, using concrete and pictorial aids.
4. The child will be able to find the product when any two-digit number is multiplied by a single-digit number, using paper-and-pencil computations.
5. The child will be able to find the product when any three- (or more) digit number is multiplied by a single-digit number, performing computations with pencil and paper.
6. The child will be able to find the product when any two-digit number is multiplied by a multiple of ten.
7. The child will be able to find the product when any two-digit number is multiplied by a two-digit number, using concrete and pictorial aids.
8. The child will be able to find the product when any two-digit number is multiplied by a two-digit number, using paper-and-pencil computations.
9. The child will be able to find the product when any three- (or more) digit number is multiplied by a two-digit number using paper-and-pencil computations.

FORMULATING HYPOTHESES

"In this SAPA sequence, students learn that hypotheses are inferences generalized to include all objects or events of the same class...In SAPA the term hypothesis is also used for a generalization about observations... Hypotheses, like inferences, can be tested. It is easier to find an observation that does not support a hypothesis than it is to make all possible observations required to support it. The more tests made that provide data that support a hypothesis, the more confident we are of the hypothesis." SAPA, Supplement to the Guide for Inservice Instruction, p. 1.

OBJECTIVES:

Given the materials and references in this MOD tray you will be able to:

1. distinguish between statements that are hypotheses and those that are not;
2. distinguish between statements that support a hypothesis and those that do not;
3. construct a testable hypothesis from a given set of observations;
4. construct more than one hypothesis from a given set of data.

INSTRUCTIONAL REFERENCES & MATERIALS:

SAPA, 70, Formulating Hypotheses a

PROCEDURE:

Distinguishing between Hypotheses and Observations

1. Read SAPA, 70, Formulating Hypotheses a. Rationale
2. Obtain materials from the MOD tray and complete the introduction.
3. Complete the sheets "Choose the Hypotheses." See the file cabinet at side of the lab. Use the image developer to check your responses.
4. Complete activity 1, 2, or 3.
5. Obtain a copy of the Group Competency Measure from the MOD tray. Read it carefully and follow the instructions. If you miss more than two of the seven tasks, you should repeat this part of the MOD again.

FINAL ASSESSMENT:

Bring to your instructor the booklet cited above and the enclosed data sheets for evaluation of the objectives.

MOD 109 Graphing I

This MOD is intended to broaden your view and skills in constructing and interpreting graphs, and to provide you with some ideas concerning the possible roles of graphs in the elementary curriculum.

OBJECTIVES:

After completing the activities you will be able to:

1. Identify and discuss some ways to use graphs as a link between other subjects and mathematics.
2. Given appropriate data and equipment, construct bar graphs, line graphs, pictographs, and circle graphs.
3. Interpret bar graphs, line graphs, pictographs, and circle graphs.
4. Locate points on both two-dimensional and three-dimensional rectangular coordinate systems.
5. Convert directed graphs to ordered pair and ordered pairs to directed graphs.
6. Describe and demonstrate sets of ordered pairs that represent the following relationships:
   a) reflexive
   b) symmetric
   c) transitive
6. State and demonstrate the meaning of one-to-one correspondence.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Graphs
2. Elementary mathematics textbooks
3. Newspapers, magazines, etc. with graphs
4. Graph paper
5. Ruler, compass and protractor
6. Slide/tape "Overview of Graphs in the Elementary School"

PROCEDURE:

1. In MMP, Graphs, read "Overview of Graphs in the Elementary School" or view the MMP slide-tape, "Graphs in the Elementary School."
2. In MMP, Graphs, do Activities 1, 2, 4, 10, and 11.
3. Look through some current magazines and find at least three different graphs. Put them on construction paper and laminate them for your permanent file.

FINAL ASSESSMENT:

1. Bring your response sheets and graphs file to the evaluation.
2. Be prepared to respond to all topics in the objectives.

MOD 110 Controlling Variables (SAPA)
Climbing Liquids

CONTROLLING VARIABLES

"In science and in many other areas, investigators try to determine what variables or factors influence the behavior of a system and how they influence it. In order to do this they manipulate one variable, called the manipulated variable, and measure the effect on another variable, called the responding variable. The success of the investigation will depend on the ability of the investigator to prevent other variables from changing. If there is a change in only one variable and an effect is produced on another variable, then the investigator can conclude that the effect has been brought about by the changes in the manipulated variable. If more than one variable changes, there can be no certainty at all about which of the changing variables causes the effect on the responding variable." SAPA, *Supplement to the Guide for Inservice Instruction*, p. 17.

OBJECTIVES:

1. You will name at least 5 variables involved in the upward movement of liquids in materials.
2. Given the liquids, papers, and equipment necessary for the investigation, you will identify which variables are manipulated (independent), which variables are responding (dependent) and which variables are held constant (controlled) in a study of the upward movement of liquids in materials.
3. Given the materials in objective 2, you will demonstrate that:
   a. a liquid moves upward faster in some materials than in others;
   b. in a given material, different liquids move upward at different rates;
   c. temperature of a liquid affects the rise of a liquid in a given material.
4. You will formulate two questions about the systems of variables you have studied and you will seek to find an answer to at least one of your questions.
5. Given a verbal description of an experiment, you will be able to identify the manipulated, the responding, and the controlled variables.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 62, *Climbing Liquids*
2. Different types of paper
3. Detergent
4. Rubbing alcohol
5. Salt and sugar solutions
6. Baby food jars, beakers or other containers
7. Clothespins on wires
8. Hot plate
9. Thermometer

FINAL ASSESSMENT:

1. Present your lab sheets and graphs to cover objectives 1 and 2.
2. Discuss your results pertaining to objective 3.
3. Present your questions and answers completing objective 4.
4. See objective 5.

PROCEDURE:

Hold a strip of paper so that one end of the strip is immersed in a container with 10 millimeters of water and observe what happens. Support the paper by the clothespin on a wire rod. Support the rod by a clamp on a pole. List below the factors or variables that might possibly affect what happens.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Others ______________________________

In each experiment you perform consider the responding variable to be the rise of liquids in materials. Design experiments to answer the following questions:

1. Will water move higher in some materials than in others?
2. Does the width of the blotting paper make a difference in how far the water rises?
3. Will some liquids (other than water) move faster or slower than water?
4. Does the depth to which you immerse the blotting paper in the water affect the height to which the water rises?

5. Does the temperature of the water in each vial affect the height to which liquids rise?
6. Does paper that has been wet and dried out behave like new paper?

In the space below, describe your investigations. Identify in each case which variables are manipulated and which are held constant. You should complete at least three demonstrations regarding the rise of liquids in materials. Please return liquids to containers after use. CAUTION: If you use the thermometer, please handle it with care.

QUANTITATIVE OBSERVATIONS NEED TO BE RECORDED TO MAKE A GRAPH!

Trials	Manipulated Variable (independent)	Responding Variable (dependent)	Variables Held Constant (controlled)	Observations
1.				
2.				
3.				

Plot the data you have collected for each investigation on graph paper. Make some predictions from your graphs and test these predictions in a final experiment.

Discuss below the results of your demonstrations fulfilling objective 3:

A child psychologist wants to determine whether nursery school attendance has any effect on children's social perceptiveness. He scores social perceptiveness by asking standard questions about a set of pictures which depict a variety of social situations, and then he rates each child's responses. By this device he obtains a score between 0 and 100 for each child. Higher scores represent higher social perceptiveness.

To test the effect of nursery school attendance on children's scores in social perceptiveness, he obtains 8 pairs of identical twins to serve as subjects. Without selection, 1 twin from each pair is assigned to attend nursery school for a term. The other twin in each pair is to remain out of school. At the end of the term, the 16 children are each given the test of social perceptiveness. Note: Identical twins are genetic equals.

In the above paragraphs determine what are the manipulated variables, the responding variables, and the controlled variables. Can you list any other variables you would like to control?

Write at least 2 questions resulting from this MOD.

1.

2.

Give an answer to at least one of the above questions.

Please do not consult SAPA 62, Climbing Liquids, until after you have carried out the activities outlined in this MOD.

MOD 111 Graphing II

This MOD is to allow you to explore graphing as a part of many different elementary school activities and subject areas other than mathematics.

PREREQUISITE: MOD 109

OBJECTIVES:

At the conclusion of this MOD you should be able to:

1. Prepare a lesson plan for an activity involving graphing, including objectives, prerequisite skills needed, and appropriate grade level.
2. Describe graphing activities for subject areas of the elementary curriculum other than mathematics.
3. Plan an activity for children involving coordinate systems in some elementary subject.
4. List ways in which coordinate systems are involved in a child's life outside the classroom.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Graphs
2. Several elementary mathematics textbooks, found in Resource Center
3. Reference books on games for graphing

PROCEDURE:

1. In MMP, Graphs, do activities 3, 5, and 7.
2. Prepare a game to be used in a lesson on graphing for your permanent file.
3. Prepare a lesson plan for teaching in MOD 113.

FINAL ASSESSMENT:

1. Schedule an assessment period with the instructor(s).
2. Bring your papers and game completed to the assessment period.
3. The MOD will be completed when the activities are completed, the objectives met, and the instructor(s) approves one of your plans to be used in MOD 113.

EXAMPLES OF BEHAVORIAL OBJECTIVES

FOR MOD 111

A SEQUENCE OF OBJECTIVES FOR DEVELOPING THE MULTIPLICATION ALGORITHM

1. The child will be able to state the products for all multiplication combinations through 9 x 9.
2. The child will be able to find the product when a multiple of ten is multiplied by a single-digit number.
3. The child will be able to find the product when any two-digit number is multiplied by a single-digit number, using concrete and pictorial aids.
4. The child will be able to find the product when any two-digit number is multiplied by a single-digit number, using paper-and-pencil computations.
5. The child will be able to find the product when any three- (or more) digit number is multiplied by a single-digit number, performing computations with pencil and paper.
6. The child will be able to find the product when any two-digit number is multiplied by a multiple of ten.
7. The child will be able to find the product when any two-digit number is multiplied by a two-digit number, using concrete and pictorial aids.
8. The child will be able to find the product when any two-digit number is multiplied by a two-digit number, using paper-and-pencil computations.
9. The child will be able to find the product when any three- (or more) digit number is multiplied by a two-digit number using paper-and-pencil computations.

MOD 112 Interpolating and Extrapolating in Terms of Four Simple Physical Systems
Predicting (SAPA)

PREDICTING

"Predictions . . . are extensions (interpolations and extrapolations) of observations to other observations of the same kind. A prediction is tested by making further observations similar to those upon which the prediction is based." SAPA, Guide for Inservice Instruction, p. 118.

OBJECTIVES:

1. Given three systems of variables, you will manipulate each system and
   a. record in an orderly table the values of the variables as the system undergoes changes;
   b. construct a graph to represent the relationship between the variables;
   c. make predictions by extrapolating or interpolating as directed in each system.
2. For a fourth system involving time, velocity, acceleration, and distance, you will:
   a. perform appropriate calculations to generate data and record the data in orderly tables;
   b. construct graphs to represent the relationships between the variables;
   c. make predictions by extrapolating as directed;
   d. compare the nature of the relationships by comparing the graphs.
3. You will invent and set up your own system of variables different from the ones above, manipulate the system, and make a prediction on the basis of your observations.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SAPA, The Basic Science Processes, in the MOD tray (Reference only)
2. Graph paper
3. Small graduates and medicine droppers
4. Bolts and nuts
5. Balance*
6. Springs and spring stands
7. Weights
8. Meter sticks
9. SAPA, 48, Bouncing Ball (Reference only)
10. SAPA, 53, Suffocating Candle (Reference only)

FINAL ASSESSMENT:

See objectives 1, 2, and 3 above.

---

* Note: Use either a triple-beam balance or a double-arm type.

PROCEDURE:

Manipulate each of the following systems, and obtain data showing the relationship of one variable to the other. Note which is the manipulated variable and which is the responding variable. Be ready to submit an orderly table of data and a graph corresponding to each system. Be ready to show how you can make predictions from each graph.

System #1: One ml. equals the volume of __________ drops.

Given a medicine dropper and a graduate, investigate the relationship between drops and ml. Get data for 1, 2, 3, 4, and 5 ml. Extrapolate to predict the number of drops in 7 ml. Different medicine droppers will give different sized drops.

Predicted number of drops for 7 ml __________

Measured number of drops for 7 ml __________

- -

System #2: One bolt weighs as much as __________ nuts.

Given the bolts and nuts provided in the laboratory, set up a table showing the relationship between their weights. Get data for 1, 2, 3, and 4 bolts. Extrapolate to predict the number of nuts for 5 bolts.

Predicted number of nuts for 5 bolts __________

Measured number of nuts for 5 bolts __________

- -

System #3:

Given the springs, meter sticks and weights provided, collect data and record it in a way that shows the relationship between the stretch of the spring and the weight hung from it. See how inventive you can be in getting this data. Get data for 10, 20, 30, and 40 additional grams. Extrapolate to predict the stretch for 50 g.; interpolate to predict the stretch for 25 g. Then verify your predictions in the laboratory.

Predicted stretch for 50 g. ________________

Measured stretch for 50 g. ________________

Predicted stretch for 25 g. ________________

Measured stretch for 25 g. ________________

System #4:

Consider an object moving at a constant velocity of 2 meters/second. Plot the points on a graph of distance vs. time for 2, 4, 6, 8, 10, and 12 seconds of elapsed time. How far has the object travelled during 8 seconds?______ during 12 seconds?______ How far will it go in 17 seconds?______ Do you have to figure this, or will the graph show you (by extrapolating)?

Now consider an object in free fall. (It could be dropped off a tall building or from an aircraft.) As it falls, it will accelerate (due to gravity) by 9.8, or almost 10 meters/second, each second it is in a state of free fall. Thus, at the end of second #1, its velocity is 9.8 m/sec. At the end of second #2, its velocity is 19.6 m/sec, etc. Plot the velocity at 1, 2, and 3 seconds. Now determine the velocity at 4 and 6 seconds, by extrapolation on the graph.

Now, on a separate graph, plot another set of points to denote the distance the object has fallen at the end of 1, 2, 3, and 4 seconds. Remember, the velocity is changing by 9.8 m/sec while in free fall. To determine distance during a period of acceleration, multiply average velocity by time. Thus, at the end of 1 second the object in free fall has fallen $\frac{v_0 + v_t}{2} \times t$, or $\frac{0 + 9.8\text{m/sec}}{2} \times 1\text{ sec} = 4.9\text{ m}$ where v_0 = instanteous velocity at time 0 and v_t = instantaneous velocity at time t. At the end of 2 seconds it has fallen $\frac{0 + 19.6}{2} \times 2$ or 19.6 m. At the end of 3 seconds, it has fallen $\frac{0 + 29.4}{2} \times 3$, etc.

Plot the distances it has fallen in a free fall, or accelerating situation for 1 sec, 2 sec, 3 sec, and 4 sec. What is the major difference between this line and the others you have plotted?

Can you extrapolate with much accuracy for 6 or 9 seconds of free fall by using only the graph?

From the graph extrapolate distance for 6 seconds and for 9 seconds. Now calculate distance for 6 seconds and for 9 seconds. Can you extrapolate with as much accuracy on this graph as on the other two?_______ Why?

Set up or find a system of variables analogous to the first three systems above. Describe your system of variables and specify how it is to be manipulated. Record your observations, graph the results, and predict a value to be obtained by extrapolation or interpolation. Then test to see how correct your prediction is and record the results below.

MOD 113 Teaching Children: Graphing Concepts

PREREQUISITE: MODs 109, 111

OBJECTIVE:

After viewing the video program of "model" teaching your ISMEP-partner and you will plan and teach to four or five children appropriate concepts and skills on graphing concepts.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Indiana Model Teaching Video Programs on Graphing Concepts
2. Elementary mathematics textbooks
3. MMP, Graphs
4. Video-tape recorder
5. TV monitor

FINAL ASSESSMENT:

Your plan will be discussed with and approved by your instructor(s) prior to the actual teaching experience. Shortly following the actual teaching a 30-minute time period will be scheduled with your instructor(s) to discuss and evaluate the experience. Input from the classroom teacher will be sought and utilized to the extent possible.

MOD 114 Seminar on Inquiry and Children

PREREQUISITE: Completion of MOD 101
Read mimeographed reprint in MOD tray

OBJECTIVES:

At the conclusion of these seminars you should be able to:

1. list Piagetian intellectual stages in children;
2. identify the age range of each state and describe the principal characteristics of thinking in children at each stage of development;
3. list application of the aforementioned knowledge to science teaching;
4. plan lessons that will enable children to ask more meaningful questions;
5. identify convergent and divergent questions and show appropriate situations where each type of question can be employed;
6. state probable relationships between wait/time questioning and at least five possible outcomes;
7. state an average acceptable wait/time period;
8. be knowledgeable of an acceptable rate for asking questions of children.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Indiana University, The Piagetian Developmental Theory Series: Conservation and Classification, two video tapes in Resource Center
2. Video-tape projector
3. mimeographed reprints in file drawer

FINAL ASSESSMENT:

These seminars will conclude with a question-and-answer session involving the instructor and student participants. Group responses will be the determining factor of success in attaining the objectives.

MOD 115 Rational Numbers I

This MOD is intended to provide a more precise understanding of rational numbers.

OBJECTIVES:

At the completion of these exercises you will be able to:

1. Define a rational number.
2. Present physical embodiments that can be used in developing the concept of rational numbers.
3. Use pairs of numbers in presenting rational numbers.
4. Make $\frac{a}{b} = a \div b$ seem reasonable.
5. Understand and explain equivalent fractions.
6. Find common denominators by three methods.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. Cuisenaire rods, paper

PROCEDURE:

1. From MMP, Rational Numbers, do Activities 1 (parts 1 & 3), 7, 8, 9, 10, and 11.
2. Prepare a game (for a permanent file) on some concept of rational numbers used in this MOD.

FINAL ASSESSMENT:

1. Bring all work sheets and your game to the evaluation.
2. Be prepared for questions on all objectives.

MOD 116 Small Things
Observing

OBJECTIVES:

1. Learn to use and care for the microscope.
2. Learn to prepare slides of living material.
3. Describe characteristic properties of specimen observed under a microscope.
4. Make accurate observations and record them in an organized fashion.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. ESS, Small Things, Teacher's Guide
2. Dropper, pepper, thread, microscope slides, cover slips, onion, knife, hand lens, forceps, methylene blue, eosin y, iodine stain, toothpicks, scissors

Suggestion: Use the compound microscopes instead of the small, blue ones for better results.

FINAL ASSESSMENT:

1. See the objectives above.
2. Be prepared to discuss your written records with the instructor.

PROCEDURE:

1. These activities refer to investigations in ESS, Small Things, Teacher's Guide. Read the following pages as preparation:
   a. "Introduction," pp. 1-8.
   b. Investigation 1--"Don't Let the Microscope Fool You," pp. 9-15.
   c. Investigation 2--"A New Look at an Onion," pp. 31-33.
   d. Investigation 3--"Using Stains to See More about Cells," pp. 41-43.
   e. Investigation 4--"You - Instead of the Onion," pp. 47-48.
2. Using the Small Things Teacher's Guide, complete investigations 1-4, writing your answers and making your drawings on the worksheets provided in this MOD.

INVESTIGATION 1

Don't Let The Microscope Fool You

YOUR NAME:

FINDING OUT ABOUT MAKING THINGS LOOK LARGER

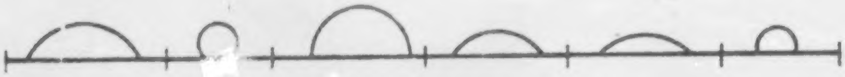
If you would like to see very small objects, you must look at them through a lens that makes things look a great deal larger than they really are.

Do you have any idea what such a lens would look like?

Take a crayon and draw a small circle on a microscope slide. Using a medicine dropper, put as much water as possible in the circle. Lift your slide and examine it from [illegible]e *side.*

Now look at the drawings below.

1. Circle the drawing that most resembles the side view of your water drop.



This water drop will now be your lens. At the bottom of the page are some words printed so small that it is very hard to read them. Place your slide with the water drop over one of the words and lift the slide until the word appears large and clear.

2. Can you read the word? What is it? ______________________

3. How does its appearance change when you look

   at it through the water-drop lens? ______________________

   ____

Using larger and smaller circles with different amounts of water in them, see if you can make a more powerful water-drop lens.

4. In the space below sketch a side view of your weakest and your most powerful lens to show their *sizes* and *shapes*.

5. Describe your water-drop lens that stands up highest from the slide. ____________________

6. Would another liquid make a more powerful lens? ____________

7. Would a clear plastic rod magnify? ____________

8. Would an empty bottle magnify? ____________

9. Would a bottle full of water magnify? ____________

10. Now draw a side view of your hand lens.

11. How would you describe a lens to a friend? ____________

____

TRY YOUR MICROSCOPE AND FIND OUT

You know that a microscope makes things look larger than they actually are. You may also know that a microscope can help you to see things that are too small for your eyes alone to see. It does other things, too. Here are some suggestions to help you find out more about the microscope.

First, let's look at the simple microscope. Using what you now know about lenses:

1. How many lenses can you find? ____________

2. Turn one of the round knobs. What does it seem to do? ____________

3. What happens when you turn the other round knob? ____________

4. What do you think is the purpose of the mirror? ____________________

____

IT TAKES LIGHT TO SEE

We usually look at things through the microscope by reflecting light through them. Look through the microscope and turn the mirror.

1. Toward what does the mirror face when it looks brightest in the microscope? ____________________
2. Which way does the mirror face when it looks darkest in the microscope? ____________________
3. What happens when you cup your hand around the mirror? ____________________
4. Can you still see through the microscope with your hand around the mirror? ____________________

HOW MUCH CAN YOU SEE AT ONE TIME?

Look at the small words at the bottom of the page and choose one to look at through your microscope.

1. How much of the word do you *think* you can see through the microscope at one time? ____________________

Tear the word off and try it. Put it on a slide and wet it to make it stick to the slide better. This word is your **specimen**, or object you are going to look at. Insert the slide under the lens strip. Then carefully lower the lens until it *almost*, but not quite, touches your slide.

Look through the lens as you turn the focus knob carefully to move the lens up away from the slide. Adjust the mirror so that you get as much light as possible. If you have trouble focusing, ask your teacher for help.

2. How many letters are in the word? ____________________

3. How many of the letters can you see at one time through the microscope? ______________________

4. How much of the word can you see? ______________________

Now take a scrap of plain paper and draw on it a circle the size you think you will be able to see all at once through the microscope. Wet the paper, put it on a slide, and look at it through the microscope.

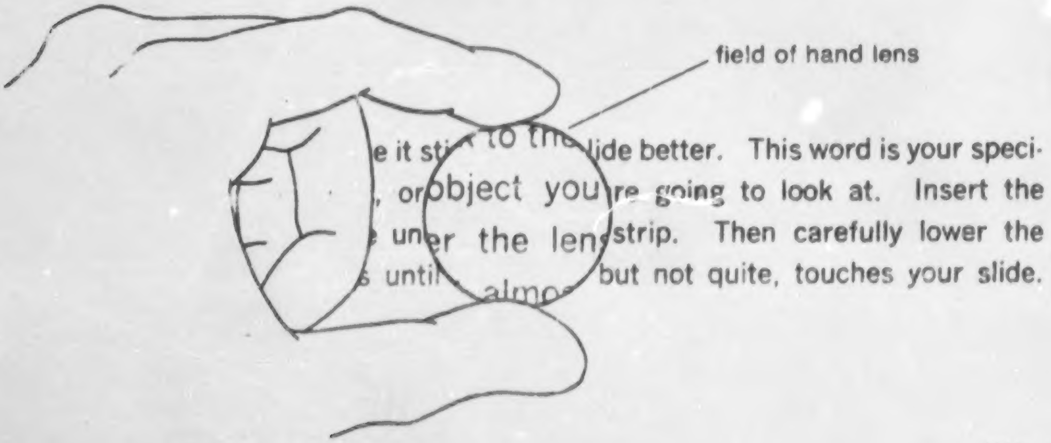
5. Can you see the whole circle? ______________________

6. Make a copy of your circle in the space below.

If you can see the whole circle, good! If not, keep drawing circles on scraps of paper and looking at them through the microscope until you get the largest circle that is the right size.

7. As you make each circle, copy it in the space above.

This will give you a record of how many circles you drew and what their sizes were. Mark the circle that is just exactly the right size to see through your microscope. This circle represents the size of your microscope **field.** The first time we looked at a circle through a microscope, we were very surprised at how small a field the microscope had.


field of hand lens
e it sti to the lide better. This word is your speci-
, or object you re going to look at. Insert the
e under the lens strip. Then carefully lower the
s until almos but not quite, touches your slide.

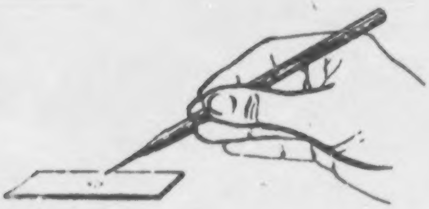
INVESTIGATION 1

Don't Let The Microscope Fool You

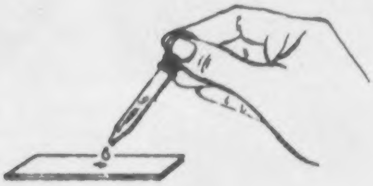
YOUR NAME:

HOW TO PREPARE A SLIDE

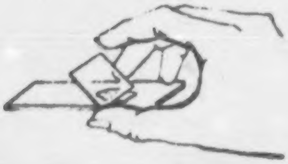
You have been looking at letters and circles. Use your microscope now to look at something else. Try dust, pepper, thread, or some other small object. Whatever you put on your slide is called a **specimen.**



First, put your specimen on the slide.



Very carefully add a single drop of water.

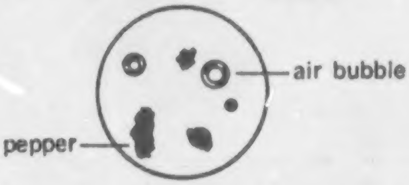


To cover the specimen with a cover slip, touch one edge of the cover slip to the drop of water, then gently lower the cover onto the specimen. Keep the bottom of your slide dry.

1. What specimen did you use? ______________________________

Look first at your specimen with your eyes alone and then look at it through the microscope.

2. Do you see bubbles? ☹ __________



3. What does the microscope seem to do to your specimen? ____________________

Try making a slide without using a drop of water.

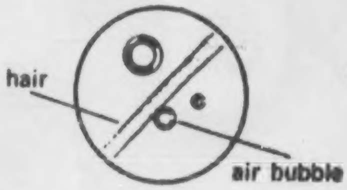
4. Can you see the specimen more clearly with or without water? ____________________

MEASURING THE SIZE OF SPECIMENS

So that you won't be fooled by your microscope, you need some way to measure how small the things you see through it actually are. One way to do this is to compare them with something else whose size you already know.

1. Name several very small things that you might put on your microscope slide to use as a measure. ____________________

One small thing that you might use for a measure is a hair. Pull a hair from your head. Look at it carefully with your eyes alone. Cut off about 1 inch from the hair and make a slide with this piece.



2. How many hairs side by side would you need to fill the field of your microscope? ____________________

3. Just for fun, how big would your head have to be if your hairs were really the size they look through your microscope? ☺ ____________________

Make a slide with a piece of thread and a hair side by side.

4. How many hair widths wide is the thread? ____________________
(You may abbreviate "hair width" as hw.)

Try the other small things that you named as measures.

5. Which of your measures works best for you? ____________________

INVESTIGATION 1

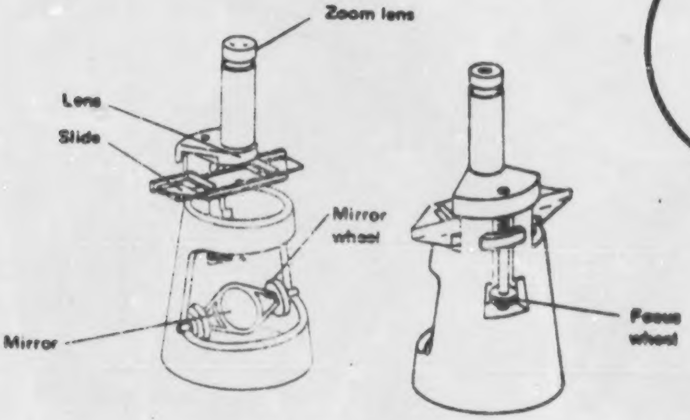
Don't Let The Microscope Fool You

YOUR NAME:

MAKING A COMPOUND MICROSCOPE

Tear off a small word from the bottom of this page. Dampen the paper and put it on a slide. Look at it through your microscope.

1. In the space at the right draw a picture of what you see. Now place the zoom lens attachment on the microscope as in the picture.



2. Look through the microscope at your slide. You may have to extend the zoom and refocus the microscope to get a clear image. You may need more light. When you can see your slide clearly, look at it carefully. You have changed your single-lens microscope to a compound microscope. The second lens is called the **ocular lens.**

Both the simple and the compound microscope can be used in your study, but the compound microscope might fool you yet!

3. Draw a picture in the circle of what you now see.

4. When you use the second lens, are the letters larger or smaller than they looked earlier? ____________

5. Do the letters look right side up or upside down? ____________

6. Did you place the word on the slide right side up or upside down? ____________

7. Look and be sure.

WHEN THINGS MOVE UNDER THE MICROSCOPE

Remove the attachment and look through the simple microscope at the slide with the small word on it. While you are looking through the microscope, pull the slide slightly to the left.

1. Are the letters still right side up or are they upside down? ____________

Pull the slide slightly to the right.

2. Which direction did the letters move then? ____________

Again change your simple microscope into a compound one by adding the second lens. Focus the specimen in your microscope and again pull the slide slightly to the left.

3. Which direction did the letters seem to move? ____________

Pull the slide slightly to the right.

4. Which direction did the letters seem to move? ____________

5. What do you think will happen when you look in this compound microscope and move your slide away from you? ____________________

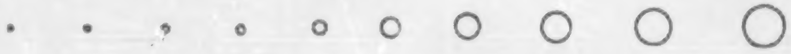
____

6. Were you right in your guess? ____________________

If you were not, look through the compound microscope while your partner moves the slide. Tell him which direction he moved it. Continue to do this until you can state correctly which way the slide is actually moving when it seems to move to the right, to the left, away from you, or toward you.

SEEING MORE ABOUT SOMETHING BUT LESS OF IT

Earlier you looked at small circles through your microscope. Look now at the family of circles below.



Imagine putting them one by one under the simple microscope.

1. Mark the circle you think you would be able to see all at once in the microscope field.

Tear off a circle from the bottom of the page. Moisten the paper and put it on a slide.

2. What do you see in the microscope? ____________________

If you could not see it all, try another circle until you have the right size.

3. If you looked at the same circle under the compound lens, would you still be able to see all of the circle? ____________________

Add the second lens to change your simple microscope into a compound one. Now look at the circle again.

4. Can you see all the circle in the field of the higher-power microscope? ______________________

5. What does increasing the power of the microscope do to the size of the circle? ______________________

____

6. What does increasing the power of the microscope do to the size of the field? ______________________

____

CARING FOR YOUR MICROSCOPE

Is The Lens Clean?

Is The Lens In Place Properly?

Is The Mirror Free From Dust?

Have You Learned To Take Care Of Your Equipment?

Can You Answer Yes To All Of These Questions?

INVESTIGATION 1

Don't Let The Microscope Fool You

YOUR NAME:

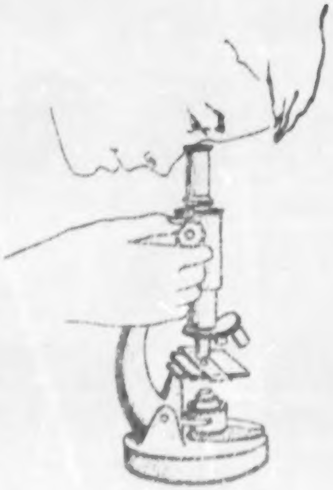
FINDING OUT MORE ABOUT A COMPOUND MICROSCOPE

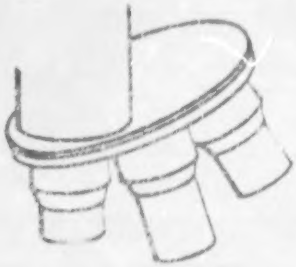
Perhaps there is a regular compound microscope available to you.

1. Does it have several lenses of different sizes? ____________________

If so, this worksheet will help you to learn more about the microscope.

First look at the numbers on the lenses of the microscope and label them on the drawing below. Or if your microscope has a different number of lenses, sketch them in the space below and number them.





2. Which lens do you think would make objects look largest? ____________________

Tear off a small word below, moisten it, put it on a slide, and focus one of the lenses. Then refocus the microscope, using a second lens. Repeat if your microscope has a third lens.

3. Which lens makes the word look largest? ____________________

4. Which is the next most powerful lens? ____________________

5. List the lenses from the lowest power to the highest. ____________________

6. Which lens do you think would have the largest field? ____________________

Let's check. Make a tiny x on a small piece of paper. Put the paper on your slide and look at it with each lens.

7. Which lens makes the x look largest? ________________________

8. Which lens has the largest field (shows the most area of the x)? ________________________

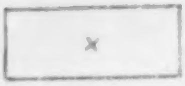
9. When you use a high-power lens, do you see more of the x or less? ________________________

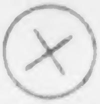
10. When the x looks larger, does the field become larger or smaller? ________________________

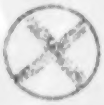
Look at the drawings below.

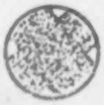
11. Write a number 1 beside the drawing that looks most like your x when you use lens number 1.

12. Similarly number the drawings that correspond to lens 2 and lens 3.









Now fill in the blanks in the sentences below.

13. The higher-power lens has the ________________ field.
(larger, smaller)

14. The lower-power lens has the ________________ field.
(larger, smaller)

15. The higher-power lens shows ________________ of the specimen.
(more, less)

16. The lower-power lens shows ________________ of the specimen.
(more, less)

17. The lower-power lens makes the specimen look ________________
than the higher-power lens. (larger, smaller)

18. The lower-power lens shows ________________ of the field than the
higher-power lens. (more, less)

INVESTIGATION 2

A New Look At: An Onion

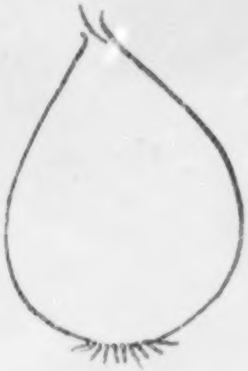
YOUR NAME:

WHAT'S INSIDE AN ONION?

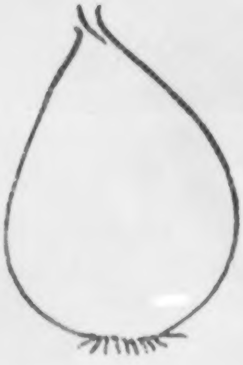
No doubt you have seen onions often.
But have you really looked at an onion? Look at an onion carefully. What do you see?

Perhaps you see the dried remains of rootlets and the messy end where the leaf blades died off. Did you notice the outer skin? Peel off some outer skin. Think about what the onion might look like inside.

1. Sketch what you *think* you would see if you cut the onion lengthwise from the leaf end to the root end.
2. Now slice the onion lengthwise and sketch what you *see*.

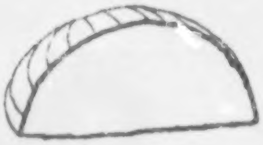


I THINK

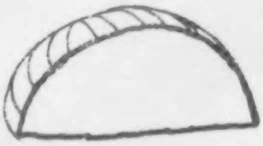


I SEE

3. Next sketch what you *think* you would see if you cut one of your onion slices in half across the roundest part.
4. Cut through the roundest part and sketch what you *see*.



I THINK



I SEE

YOU CAN SEE EVEN MORE

Perhaps you think you have really seen an onion. Have you? You can help your eye by looking at an onion with a hand lens.

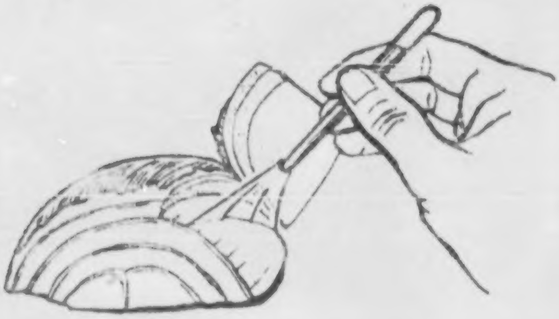
1. How does the lens help you to see the onion? ______________________________

Layer by layer, gently separate the onion. Look at one of the layers through the hand lens. Look at its inner edge.

2. What do you see that you had not seen before? ______________________________

Break a layer and use your tweezers to pull it apart. Try to find what separates the parts of the layers.

3. What did you find? ______________________________



Now carefully peel off a piece of the thin skin found on the inside of each layer. Try to lay it on a slide without folding it. Hold it up to the light and look at it through your hand lens.

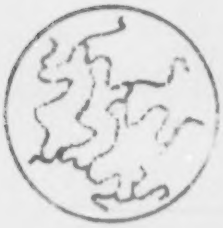
4. What can you see? ______________________________

HELPING YOUR EYE TO SEE STILL MORE

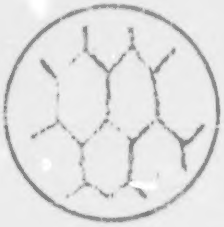
You can use the microscope to see still more of an onion. Take a piece of the thin onion skin smaller than your fingernail. Place it on a microscope slide and put a drop of water on it. Put the cover slip over the onion skin—carefully!

Look at your slide through the microscope and tilt your mirror back and forth. Does adjusting the light help you to see the onion skin better? Turn the mirror back and forth. Get a bright field in your microscope. Get a dark field in your microscope.

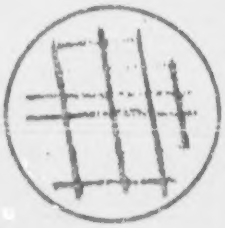
1. Do some parts of the specimen stay light and shiny more than others? ______________________________
2. Which of the drawings below looks most like what you see of the onion with your microscope? ______________________________



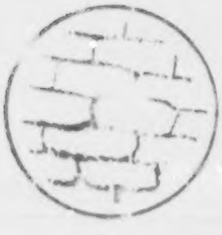
A



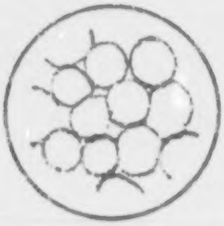
B



C



D



E

Sketch in the circle what your specimen looks like.

3. How would you describe the shape of the things you see? ____________________

4. Do they seem to have anything in them? ____________________

5. Are the blocks all exactly the same size? ____________________

6. Are they about the same size? ____________________

7. Are they all exactly the same shape? ____________________

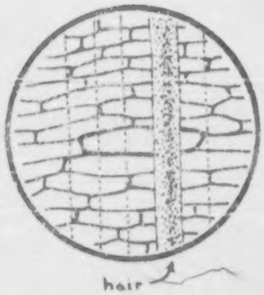
8. Are they about the same shape? ____________________

MEASURING THE SIZE OF THE UNITS

The units in a layer of onion are so small that they cannot be seen except through a microscope. To find out what size they really are, you can compare them with the width of a hair.

Take off the cover slip of your slide. Add another drop of water to the onion skin; then place a short piece of hair across the skin. Replace the cover slip carefully.

You may have to move the slide around to see the hair in your microscope. If you have made a permanent measuring device you may use it here.



1. How many widths of your hair could you lay side by side over the *length* of one block? ____________________

2. How many widths of your hair could you lay side by side over the *width* of one block? ____________________

There is, of course, another name for these blocks you have just seen and described. For a moment pretend you do not know it. Imagine that you are the first person ever to look at an onion skin through a microscope. What an exciting discovery!

3. What would be a good name for these blocks? ____________________

INVESTIGATION 3

Using Stains To See More About Cells

YOUR NAME:

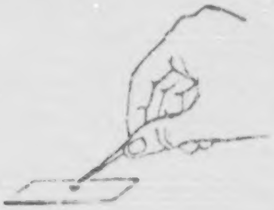
Make a slide of the skin from inside a layer of onion. Look at it through the microscope. Look at a single cell.

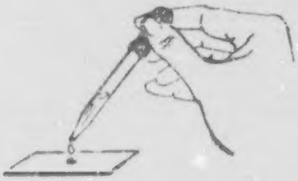
1. What do you see inside of one of the cells? ______________________________

____

There are several ways of seeing parts of the cell better. Remember how white the onion cells are. One way to make them easier to see is to use color. We refer to coloring cells as "staining" and we call the colors **stains.**

Try the stain, methylene blue, on a piece of onion skin on a slide. With a toothpick add a bit of stain. Then add a drop of water and the cover slip.





Now look carefully through the microscope at your specimen for a while.

2. What do you now see inside the cell? ______________________________

3. In the rough outline of the single onion cell below, fill in the appearance of the stained cell, just as you see it through the microscope.

METHYLENE BLUE STAIN

Try a second stain. You know that iodine will stain your fingers. Do you suppose it will do the same for a piece of onion skin?

Make a slide using one toothpick drop of iodine stain and one drop of water on a piece of onion skin.

4. What color does the iodine stain the onion cells? ______________

5. In the cell outline below fill in the stained cell just as you see it in the microscope.

IODINE STAIN

Try a third stain. Use eosin Y.

6. In the cell outline below fill in the stained area just as you see it in the microscope.

EOSIN Y STAIN

Compare your three sketches.

7. Does eosin Y stain the same part of the cell as iodine? ______________

8. Does eosin Y stain the same part of the cell as methylene blue? ______________

9. If you were studying just the little spots which you see inside some of the onion cells, which stain would you use? ______________

10. What other colored liquids might work as stains on the onion cells? ______________

See if you can get some of the things you have listed as stains. Try them.

11. What happened? ______________

INVESTIGATION 4

You–Instead Of The Onion

YOUR NAME:

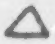
You have been looking at the cells of an onion. In other words, you have been looking at plant cells. Now you are going to investigate cells of an animal–you!

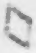
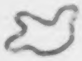
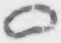
You can collect some human skin cells. These are called **epithelial** (epith-EE-lee-al) cells.

Place a small drop of clean water on a clean slide. Take a clean toothpick. Use the blunt flattened end and *gently* scrape the inside of your cheek. You do not have to scrape hard. Touch the material collected on the toothpick to the drop of water on the slide. Then add a small drop of methylene blue. Cover with a cover slip.

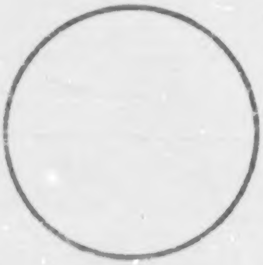
You may not be able to see anything of your specimen until you look at it through the microscope. If you cannot see anything then, try again.

1. Circle the drawing below which looks most like a human epithelial cell.



2. Sketch below what you see through your microscope.



3. How are epithelial cells like onion bulb cells? ______________________

____

4. How are they different from onion bulb cells? ______________________

____

5. Which is bigger, an epithelial cell or an onion bulb cell? ______________________

6. How would you prove it? ______________________

____

Remember our unit of measurement—the hair width or your measuring device? Put a piece of hair across the specimen. Add a drop of water and cover with the cover slip.

7. How big is the epithelial cell in hair widths? ______________________ hw

Compare this with your previous measurement of an onion cell.

8. Which kind of cell is really bigger? ______________________

Did you think to place both onion bulb cells and epithelial cells on the same slide?

MOD 117 Rational Numbers II

This MOD is designed to reinforce understanding of and skill in using operations on rational numbers.

OBJECTIVES:

After completing this MOD, you will be able to:

1. Order fractions by three methods.
2. Add and subtract rational numbers with greater confidence and understanding.
3. Explain the "why" of rules for multiplying and dividing fractions.
4. Be aware of areas of difficulty pertaining to operations for rational numbers.
5. Explain each operation with "hands-on" aids.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. Cuisenaire rods, colored chips, paper
3. Elementary school textbook series

PROCEDURE:

1. In MMP, Rational Numbers, do Activities 12, 13, 14 15, and 16.
2. Prepare a game for your permanent file on operations of rational numbers.

FINAL ASSESSMENT:

1. Bring all work sheets and games to evaluation.
2. Be prepared to demonstrate ability relative to each objective.

MOD 118 Characteristics of Living Things
Observing, experimenting

OBJECTIVES:

1. You will study a living specimen of the slime mold (Physarum) under the compound and stereo-microscopes and observe its general structure.
2. After observing the slime mold for a two or three day period, you will be able to discuss evident properties that exemplify the living characteristic of growth and/or reproduction.
3. After observing the slime mold, you will be able to discuss observable phenomena that exemplify the living characteristics of nutrition and excretion.
4. On the basis of your experimentation with the slime mold, you will be able to cite phenomena you have seen that exemplify the living characteristics of nutrition and excretion.
5. On the basis of your experimentation with the slime mold, you will be able to cite phenomena you have seen that exemplify the living characteristics of responsiveness and repair.
6. You will design and carry out one experiment with the slime mold in addition to the activities in this MOD.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Carolina Tips--The Slime Mold Life Cycle
2. SAPA, 16, Living and Nonliving Things
3. SCIS, Life Cycles Teacher's Guide, What is Alive?
4. This MOD, pp. 2-5
5. General biology references on the characteristics of living things
6. Materials needed for the activities

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to show the instructor all data and answers in the activities
3. Describe your own experiment on the slime mold and discuss your results with the instructor.

PROCEDURE:

General Information

All things in nature can be divided into two main categories - living and non-living. Both are composed of the same kinds of basic elements or atoms. Both living and non-living things are composed of combinations of these basic elements. Living and non-living forms cannot be distinguished on the basis of these combinations alone. In living substances combinations of basic elements are found in compounds and molecules that are not found in non-living forms. But on the basis of these differences alone, living and non-living forms cannot be distinguished. If only structure or composition were used to distinguish between living and non-living forms, then an organism that just died would be categorized as living because it still had the same basic structure and composition that it had as a living organism. Some other criterion is needed to distinguish between living and non-living forms. This criterion is activity or function. A living organism must constantly expend energy to maintain the living state. If it is in the living state, it must maintain a specific structure or order so that it can carry on the required activity. All non-living things tend to become less ordered or more randomly distributed throughout nature. Non-living things, through the action of physical forces of nature, are constantly broken down to their basic elements. These same physical forces act upon living organisms. In order to resist the effects of these forces, a living organism has to obtain and expend energy. In doing so it shows at least three kinds of activities and functions. It is because of these activities and functions that something can be categorized as living.

1. Nutrition

An organism has a constant need for nutrition. The substance of a living organism is constantly wearing out or breaking down. An organism must take in new materials to replace lost or worn out materials or parts. Some of the new materials will be used for energy in making or synthesizing new parts. If an organism is large, it must have a means of moving these new parts from one part of the organism to another. In this way, movement, growth, and reproduction can be seen as one activity of the living organism.

2. Irritability

A living organism is constantly subjected to those forces of nature which tend to make it disordered or random. In order to maintain the living state and to resist these forces, the living organism must be able to detect and react against them. To sense resisting forces is a necessary activity of the living organism. This characteristic is called irritability.

3. Responsiveness

An organism that is sensitive to its environmental pressures must also have the ability to respond to these as a means of protection. This kind of activity is the characteristic of responsiveness.

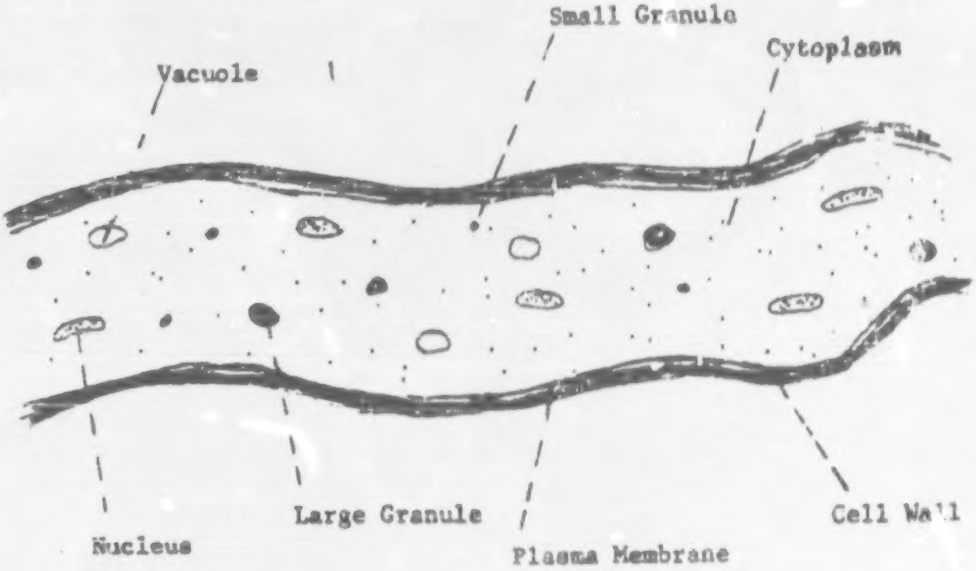
Each student will have a petri dish containing an active growth of the slime mold - Physarum polycephalum. Obtain an agar plate from the instructor and inoculate as instructed. Physarum is a living organism composed of one large cell. The cell differs from other typical cells for it is comparatively large and has many nuclei instead of only one nucleus per cell. Note that the large cell is shaped like a tree with many branches. Each branch is surrounded by a cell wall and contains a streaming substance called protoplasm. The protoplasm of any cell is a system or combination of three kinds of liquid media. First, it is a solution that has a liquid base (water) in which are dissolved a variety of chemicals such as salts, acids, bases, and other simple organic substances. "Dissolved" means that each molecule of a substance is separated from its own kind by the solvent (water) molecules. The molecules of the substance stay in solution because their own kinetic energy keeps them in motion and separated from each other. Second, the living substance is a colloid. A colloid has a liquid base (water) in which are dispersed a variety of other molecules. The dispersed molecules are just large enough so that their own kinetic energy does not keep them from settling to the bottom. The solvent (water) molecules because of their own kinetic energy bump into these dispersed molecules, keep them in constant random motion, and do not allow them to settle to the bottom. Molecules in a solution and in a colloid are both too small to be seen with the naked eye or with the microscope. If one looks at either a solution or a colloid with the microscope one sees nothing. The third kind of liquid medium which comprises a part of the living protoplasm is a suspension. A suspension is a liquid base (water) that has something dispersed in it. In a suspension the dispersed substance is composed of much larger particles. These particles are clusters of molecules forming specific structures as membranes, vacuoles, granules, fibers, and tubes. These structures are so large that they tend to settle to the bottom where they can be seen under the microscope. The many nuclei seen in Physarum can be considered as one class of the suspended particles. There are many other particles that can be seen. By looking at some of these fine particles under the microscope (100X) you will see that they not only are moved with the streaming protoplasm, but that they also vibrate in all directions. This is because they are being bombarded by other rapidly moving smaller molecules. This effect is called Brownian Movement. Can you see it?

Physarum is easily grown on a non-nutrient agar. The organism can not obtain food from the agar so some food source must be applied to the top of the agar. Physarum grows well on a diet of oatmeal. Small grains of oatmeal sprinkled on the agar will make Physarum move by flowing around in search of the food particles. Physarum also feeds on bacteria that grow on the oatmeal.

Physarum must be kept in the dark except when observing.

Activities

1. Examine the slime mold with both the stereo and compound microscopes (3.5 and 10X objectives). Note the structures indicated in the following diagram of a plasmodium - a section of a branch. See if you can observe Brownian Movement.



2. Observe under the 10X objective one of the streaming (cyclosis) branches. Note the rate at which movement takes place. Do the nuclei and the granules move with the cytoplasm?

3. Find a branch in which cyclosis can easily be seen. Watch this area to determine the number of times the cyclosis changes direction. Count the number of "stops" it makes during a two-minute period. How long is the stop period?

4. Repeat activity 3, but use a different branch for your determination.

5. If the cyclosis stops in one part of the plasmodium, does it simultaneously stop at all other places?

6. Place the petri dish so that an anterior part of a branch of the plasmodium is at the edge of the field of vision. Without moving dish or microscope for ten minutes, determine if the plasmodium advances or grows.

7. With the 3.5X objective in place, focus upon one of the large branches. You should be able to see streaming of the cytoplasm. With a fine pin or wire lightly touch the branch in the area you are observing. What is the effect?

8. With the 3.5X objective in place, observe a large branch again. Cut the branch with a fine pin or knife. Does the cytoplasm leak out? Does the plasmodium repair itself?

9. Does the plasmodium grow toward the food source? Can you see where it has been?

Obtain a sufficient number of agar plates from the instructor to carry out one experiment in addition to the activities in this MOD with the slime mold.

		Manipulated Variable (independent)	Responding Variable (dependent)	Variables Held Constant (controlled)	Observations
Trials	1.				
	2.				
	3.				

PAGES 6-7 OF MODULE 118 "SLIME MOLD LIFE CYCLE"
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MOD 119 Rational Numbers III

This MOD is planned to review rational numbers in the form of decimals and to use the decimal place-value system to introduce the metric system.

OBJECTIVES:

1. Review rational numbers by converting them to decimals using the division technique.
2. Explain the structure of the metric system by the decimal structure.
3. Be aware of the probable role of decimals in the future.
4. Be able to convert repeating decimals to fractional form.
5. Review operations for decimals.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2 Dienes blocks in base ten

PROCEDURE:

1. In MMP, Rational Numbers, do
   Activities 25: 1, 2, 3, and 4
   26: 1, 2, 3, 4, 5, 6, 7, 8, and 9
   27: 1b; 3a and b; 4; 6a, c, and f; 8a, b, and c
   29: 1, 2, 3, 4, and 5
   30: 1, 2, 3a, 5, and 6
   31: 1, 3, and 4

FINAL ASSESSMENT:

1. Bring all work papers to the evaluation.
2. Be prepared to demonstrate knowledge relative to each objective.

MOD 120 Teaching Children: Rational Numbers

PREREQUISITE: MODs 115, 117, 119

OBJECTIVES:

After viewing the video program of "model" teaching on Rational Numbers your ISMEP-partner and you will plan and teach to four or five children appropriate concepts and skills on rational numbers.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Indiana Model Teaching Video Programs on Rational Numbers
2. Elementary mathematics textbooks in Resource Center
3. MMP, Rational Numbers
4. Video-tape recorder
5. Television monitor

PROCEDURE:

1. View the Indiana Model Teaching Video Programs on Rational Numbers on the video-tape player.
2. Using the MMP, Rational Numbers and one or more elementary mathematics texts, make a lesson plan for a 30-minute lesson on some basic concepts involving rational numbers.
3. Have your plan approved and then carry out the teaching experience with the children.

FINAL ASSESSMENT:

Shortly following the actual teaching a 30-minute time period will be scheduled with your instructor(s) to discuss and evaluate the teaching experience. Input from the classroom teacher will be sought and utilized to the extent possible.

MOD 121 Balancing
Predicting, formulating hypotheses, inferring

PREREQUISITE: Familiarize yourself with ESS, Balancing, Teacher's Guide

OBJECTIVES:

1. You will be able to formulate a hypothesis regarding conditions for a balanced lever.
2. You will be able to explain the basic operation of the equal arm balance.
3. Using the Masonite pegboard as a balance board with a fulcrum, you will demonstrate the usefulness of the balance as tool for weighing.
4. You will be able to prepare a sensitive balance, given such materials as a needle, straw, and machine screw.

Optional

5. You will prepare a mobile which can be used in the science lab.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Primary Balancing, Teacher's Guide.
2. ESS, Materials for Primary Balancing
3. ESS, Mobiles, A Guide for Teachers

4. ESS, Teacher's Kit for Senior Balancing
5. ESS, 6-Student Kit for Senior Balancing

FINAL ASSESSMENT:

Ask your instructor for MOD 121, Final Assessment, and indicate if the examples do or do not balance.

PROCEDURE:

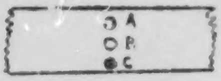
Activities:

1. "Mess about" to acquaint yourself with the equipment in the ESS Kit of Balance Materials. Refer to ESS, Primary Balancing, Teacher's Guide, pp. 10-11.

2. Continue experimenting with the materials in the kit, and also use other materials to balance different kinds of things against each other.

3. Work on the following prediction sheets. Make your prediction first, and then check your prediction.

A. On an equal arm balance with 3 holes, what happens when you use each hole as the pivot?

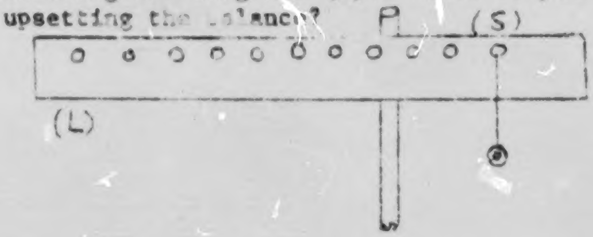


Hole A as the pivot:
Prediction: ______________________________
What happens: ______________________________

Hole B as the pivot:
Prediction: ______________________________
What happens: ______________________________

Hole C as the pivot:
Prediction: ______________________________
What happens: ______________________________

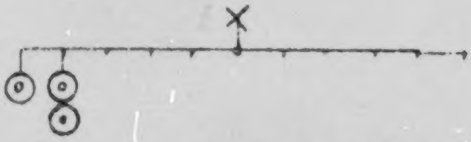
B. With the beam off center, one washer is hung on the short end (S) counterbalancing the long arm (L). Where do you add 2 or 4 washers without upsetting the balance?



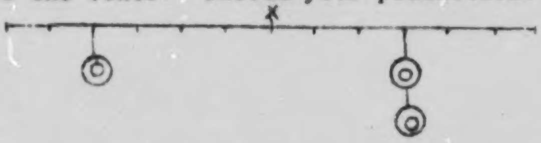
Sketch where you predict you would add the washers.

What happens when you test your prediction?

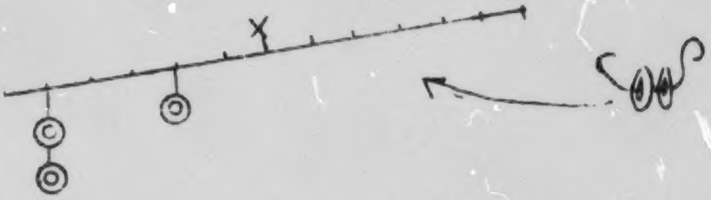
C. Can you add washers to this board to make one side the mirror image of the other? Sketch your prediction.



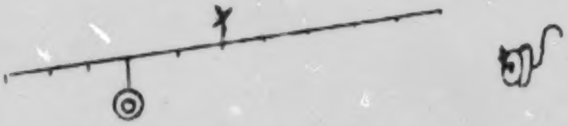
D. Can you add washers to this arrangement to make one side the mirror image of the other? Sketch your prediction.



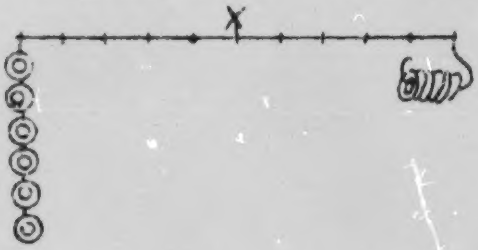
E. Can you make this board balance by adding two washers on the same paper clip? Sketch your prediction.



F. Can you balance one washer with two? Sketch your prediction.



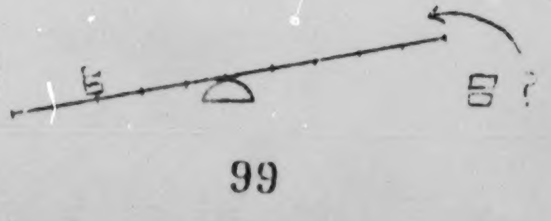
G. Will a chain of six washers balance six washers hung on one paper clip? Yes_____ No_____



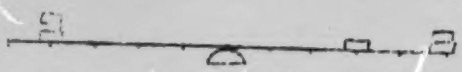
Why or why not?

Activities using the Masonite pegboard with the fulcrum below the board.

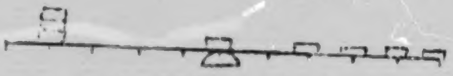
H. Given a group of washers on an unbalanced board, where would you place more washers to make it balance?



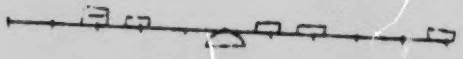
I. Will this grouping balance? Prediction: Yes ______
No ______



J. Will this grouping balance? Prediction: Yes ______
No ______



K. Will this grouping balance? Prediction: Yes ______
No ______



Drawing from your experience in activities A-K, and keeping in mind the variables involved, state a hypothesis concerning balances and their behaviors. Use the reverse side of this sheet.

4. Using the materials in the MOD tray devise a standard unit of measurement. For example: How many paper clips = 1 washer. Give your unit of measure a name.

5. Given a soda straw, machine screw, and needle, make a balance which is usable and very sensitive to weighing small articles as a grain of rice. Refer to ESS, Primary Balancing, Teacher's Guide, p. 48.

Optional activities

6. Mobiles involve balance. Read ESS, Mobiles, A Guide for Teachers, and prepare one usable science mobile of your own design.

7. If you would like to pursue this MOD further, there are problem cards available in the MOD tray for your use.

MOD 122 Newton's Laws of Motion
Formulating hypotheses

OBJECTIVES:

1. Given the study and investigation indicated on the attached sheet, you will be able to formulate rules covering cases related to Newton's three laws of motion and to compare your rules with Newton's rules.
2. You will originate a demonstration of one of Newton's three laws of motion with simple equipment of your own choice.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 37 , Describing and Representing Forces
2. SAPA, 82 , Force and Motion
3. SAPA, 80 Inertia and Mass
4. UNESCO, Source Book for Science Teaching, pp. 128-130
5. Glass, marbles, books, clothespins, board, spring balances, balloon, masking tape
6. Wilson, Physics - Concepts and Applications , pp 92 - 100, Resource Center.

FINAL ASSESSMENT:

1. Present your answers and be ready to discuss your results with your instructor.
2. Present your demonstration fulfilling objective 2 to your instructor.

PROCEDURE:

Complete activities 1-3 before you look up Newton's laws.

1. A. Over the mouth of a plastic water glass place a 5-cm. square piece of cardboard. Place a marble over the center of the glass on the cardboard. Give the cardboard a quick, sharp push horizontally with your finger. The marble should drop into the glass. Why?

   B. Take hold of the bottom book of a stack of 6 or 7 books. If you quickly jerk out the bottom book, the others should stay in place. Why?

   C. Suppose you are in a stationary car that abruptly starts moving ahead. What happens to your body? Why?

   Suppose you are in a moving car that abruptly comes to a halt. What happens to your body? Why?

   Suppose you are in a car, traveling around a sharp curve at 45 mph. What happens to your body? Why?

   D. Now, formulate a general rule encompassing all the cases under section 1.

2. A. Clamp a clothespin at each end of a long rubber band. Place a meter stick along the edge of a table top. Grasp both clothespins and stretch the rubber band along the table top. Release the clothespins at the same time and watch carefully to see where they collide. Next, clamp 2 clothespins at one end of the rubber band and one clothespin at the other end. Stretch the rubber band again. After releasing the clothespins, watch carefully again to see where they collide. More than one trial will be necessary for you to be sure of your results. Refer to the diagram in the UNESCO Sourcebook, p. 130. Describe and try to give reasons for the results.

B. Force a clothespin to remain open by tying thread around the prongs of its handle. Place it in the center of a long table. On either side of the tied prongs place pencils of similar mass. Carefully burn the thread and observe what happens. Refer to the diagram in the UNESCO Sourcebook, p. 130. Now, repeat the same procedure using objects of different masses or weights on either side of the clothespin. Observe the result carefully. More than one trial will be necessary for you to be sure of your results. Describe and try to give reasons for the results.

C. Suppose that a large heavy semi-truck and a small VW are both accelerated from 30 mph to 60 mph in 15 sec. Which one requires more force for this acceleration?

Suppose that a large, heavy truck and a small car both received the same force, the same "push." Which one would be accelerated more over a given interval of time.

D. Formulate a general rule encompassing the cases under section 2.

3. A. Place a board about a foot square over several marbles on the floor. With both feet, carefully stand on the board and then jump off. Describe and try to give reasons for what happens.

B. Hook together two spring balances. Pull at the handle of one balance while a lab partner pulls the other. As you do this try to keep the connected portions in the same location; the system remains midway between you and does not move toward either partner. Have a third person read the forces on both scales. Describe and try to give reasons for your results.

C. Blow up a long narrow balloon and keep the air from releasing. With masking tape a second person should attach a straw along the length of the balloon. Run a string at least 5 m. long through the straw. Stretch the string with the help of another person or by attaching it in the lab. Release the balloon from one end of the string track. Watch carefully to see what happens.

D. Formulate a general rule encompassing the cases under section 3.

4. Now that you have completed activities 1, 2, and 3, look up Newton's three laws of motion in a physical science book. Write them in the space below. Compare your three rules and Newton's laws. Be prepared to discuss them with the instructor.

5. Originate and carry out a demonstration of one of Newton's three laws of motion using simple equipment of your own choice.

MOD 123 Cell Structure and Function - Self Instructional Module

OBJECTIVES:

1. Define 'cell" and explain why it is important to study cells.
2. Describe the structures and major functions of the following: plasma membrane, nucleus, nucleolus, ribosome, endoplasmic reticulum (ER), Golig apparatus, lysosome, chloroplast, mitochondrion, microbody, microtubule, centriole, flagellum, cilium, vacuole, cell wall.
3. Identify diagrams and electron micrographs of the above structures and organelles.
4. Identify which of the above structures and organelles are found in prokaryotes, eukaryotes, plants, and animals.
5. Given a description or micrograph of an unknown cell, specify whether the cell is of prokaryotic or eukaryotic origin, and if eukaryotic, whether it is from a plant or animal.
6. Describe an avantage and disadvantage of the electron microscope, as compared to the light microscope.
7. Define and distinguish between the following: micron, protoplasm, organelle, DNA, prokaryote, eukaryote, pore, cytoplasm, phagocytosis, ATP, spindle apparatus, 9+2, cellulose.
8. Locate where the following functions in the cell occur: information storage, ribosome production, protein synthesis, secretion, phagocytosis, photosynthesis, respiration, ATP production, propulsion, waste storage, support of plant cells.
9. Distinguish between the structure and function of rough and smooth endoplasmic reticulum.
10. Describe the dynamic relationship between the ER, the Golgi apparatus, secretion vesicles, and the plasma membrane.
11. Describe the relationship between the cell wall and the plasma membrane.
12. Describe the differences between prokaryotic and eukaryotic cells.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. This MOD, pp. 2
2. General Biology references on cell structure and function.
3. Biology Media Instructional Materials.
4. Singer Caramate

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

INTRODUCTION:

The cell is the common unit of all life on the earth. It is the smallest unit which possesses all the properties which we associate with life--responsiveness, complex chemical activity, reproduction, etc. In order to understand life on all levels of organization--from molecules to organisms to populations--it is valuable to study life at the level of the cell.

OUTLINE:

I. Introduction
    1. The cell
    2. Sizes of cells
    3. New techniques--the electron microscope
II. Organelles -- structure and function
    1. Organelles
    2. Cell membrane
    3. Nucleus
        a. prokaryotes and eukaryotes
        b. structure and function
    4. Nucleolus
    5. Endoplasmic reticulum
        a. rough and smooth
        b. ribosomes
    6. Golgi apparatus
    7. Lysosomes
    8. Phagocytosis
    9. Chloroplast and other plastids
    10. Mitochondrion
    11. Microbodies
    12. Microtubules
        a. functions
        b. centrioles
        c. spindle apparatus
        d. cilia and flagella
    13. Vacuole
    14. Cell wall
III. Conclusion
IV. Quiz.

① Cell Structure and Fuhction

② The cell is the common unit of all life on earth. Some organisms are single-celled. ③ Other organisms are complex assemblages of many cells of various kinds.

The cell is the smallest unit which displays all the diverse properties which we associate with life--reproduction, complex chemical activity, responsiveness, and so on. Thus, it is valuable to study life on the cellular level.

④ The largest cell is an ostrich egg, but most cells are much smaller than this. ⑤ Most cells are 1 to 10 microns in diameter. A micron is 10^{-6} meter, or one millionth of a meter. So most cells are 1/1000th to 1/100th of a millimeter in diameter. The smallest cells are less than 1/2 micron, or 1/2000th of a millimeter across.

These measurements are rather difficult to visualize. Perhaps comparing an average cell to a familiar object, a penny, would be helpful. ⑥ If a penny were enlarged to the size of a football field, a cell, enlarged to the same degree, would be about the size of a penny.

⑦ To early observers, the tiny cell was a membranous bag filled with a jelly-like fluid called protoplasm. It was discovered early that most cells contain a spherical dark structure called the nucleus. ⑧ Some cells were seen to have thick walls, and maybe little granules like the green structures in these plant cells. But observation of cells under a light microscope is limited by the physics of light. The wavelengths of visible light are simply too long to reveal the details of cellular structure. Thus, until the middle of the twentieth century, it was impossible to see the fine structure of the cell and really unravel how cells work, how they live.

Perfection of the electron microscope and new biochemical techniques in the 1940's and 50's changed our whole concept of life at the cellular level. ⑨ The electron microscope focuses a beam of electrons on the specimen, rather than a beam of light. Because the electrons have much shorter wavelengths than light, ⑩ the electron microscope reveals much smaller structures than can be seen under a light microscope. Structures which appeared to be featureless granules floating in an amorphous protoplasm can now be delineated as complex systems of membranes, compartments, and tubes.

⑪ These subcellular structures are collectively called organelles; there are several organelles common to most cells. We are just beginning to understand the structures and functions of these organelles.

Before we go on, I should point out that the photographs taken with an electron microscope--they are called electron micrographs--are still inaccurate representations of life. A specimen for the electron microscope must be killed, stained with various harsh chemicals, mounted in plastic, and sliced very thin. The prepared specimen is then popped into a vacuum chamber for observation. Needless to say, this is very rough treatment for a living thing. What we see in an electron micrograph is not alive. It is literally a shadow of life. Nevertheless, we can learn much about the life of the cell from electron micrographs. So let's get started.

⑫ All cells are bounded by a thin, delicate membrane, called the cell membrane or plasma membrane. ⑬ This membrane appears to have a bilayered structure, sometimes called the unit membrane structure. An obvious function of the cell membrane is to protect the cell and hold it together. But the membrane has a more dynamic function than this--. It selectively lets certain molecules into and out of the cell, and stops other molecules. ⑭ This property is called selective permeability. Because they are selectively permeable, membranes play a major role in controlling the chemical activity of cells. The cell membrane also serves as the site for many complex chemical reactions and is involved in communication with other cells. Organelles are bounded by membranes similar in structure to the cell membrane.

⑮ The largest, most obvious organelle found in many cells is the nucleus, the large, dark, spherical body observed by early microscopists. Note that I said the nucleus is found in many cells. Not all cells have nuclei; as a matter of fact, some cells do not have any membrane-bound organelles at all. Thus, cells can be divided into two major categories:

⑯ Cells which lack a nucleus are called prokaryotic cells or prokaryotes, from Greek words meaning "primitive nucleus". Cells which possess a nucleus are called eukaryotic cells or eukaryotes. . "Eukaryote" means "true nucleus."

⑰ The prokaryotes are simple one-celled organisms--bacteria and blue-green algae. Eukaryotic cells are more complex. The eukaryotes are the organisms with which we are more familiar--plants, animals, fungi, and protozoa. (Protozoa are one-celled eukaryotes.) ⑱ Note in comparing prokaryotic and eukaryotic cells that prokaryotic cells not only lack a nucleus, but other membrane-bound organelles as well.

⑲ At this point, stop the tape and start a "Cells and Organelles Checklist." Label one column "prokaryotes", the other "eukaryotes". As we go along, you can fill in which structures are present in each type of cell. For starters, fill in that prokaryotes are represented by bacteria and blue-green algae. Eukaryotes are plants, animals, and fungi. Both have cell membranes, indicated by a plus. Eukaryotes have a nucleus, indicated by a plus. Prokaryotes lack a true nucleus; we will indicate this with a minus.

⑳ Now--back to the nucleus. The nucleus is the place where the cell's hereditary information is stored in molecules of DNA. DNA more-or-less contains the "blueprints" for making proteins, and proteins are the molecules which make up a large part of the structure of the cell as well as guiding the chemical processes of the cell. ㉑ Thus, the primary function of the nucleus is information storage.

㉒ The nucleus is surrounded by a double membrane; this double membrane is sometimes called the nuclear envelope. There are pores in the nuclear envelope through which molecules can move between the nucleus and the rest of the cell.

Although prokaryotes lack true nuclei, their hereditary information is carried in molecules of DNA. The area of the prokaryotic cell where the DNA is located is sometimes called the nuclear area or nucleoplasm.

㉓ A dark spherical area called the nucleolus is sometimes seen within the nucleus. The nucleolus is a dense, dark lump of DNA, protein and other chemicals, where tiny structures called ribosomes are assembled. The DNA in the area of the nucleolus carries the information for making parts of the ribosomes. We will discuss ribosomes in a moment. Since only eukaryotic cells have nuclei, only eukaryotic cells have nucleoli.

㉔ Let's leave the nucleus and explore the rest of the cell. The material of the cell outside the nucleus is called the cytoplasm. ㉕ The most conspicuous organelle in the cytoplasm of many cells is a complex network of folded membranes, called the endoplasmic reticulum. The endoplasmic reticulum, or ER for short, is a site of intense biochemical activity. It is composed of a network of flattened sacs or tubes called cisternae.

㉖ There are two types of ER--rough ER and smooth ER--as shown in this diagram. Rough ER is made rough by the tiny, globular ribosomes which cover its surface. Ribosomes are tiny protein and nucleic acid "machines" which assemble proteins for use in the cell. ㉗ Thus, the endoplasmic reticulum serves as the site of protein synthesis. Cells which produce a lot of protein are often filled with rough ER. Smooth ER, incidentally, may be associated with the synthesis of other complex molecules, such as hormones.

㉘ Even though prokaryotes lack ER, they nevertheless possess free ribosomes, seen in this picture. These prokaryotic ribosomes happily synthesize proteins without being attached to membranes.

㉙ A peculiar structure found in many eukaryotic cells is sort of stacks of flattened bags called the Golgi apparatus, seen in cross-section in this picture.

㉚ Perhaps this diagram will help you to visualize the Golgi apparatus. Picture a stack of squashed ballons, with connecting tubes and smaller ballons being pinched off at the edges. The Golgi apparatus appears to be a packaging center for materials produced in the cell, particularly proteins.

㉛ In an experiment, radioactive amino acids were supplied to a cell, and the cell used them to make proteins which were radioactive. At first, the radioactivity was detected in the ER, the site of protein synthesis. (32) About half an hour later, the radioactive proteins were found in the Golgi apparatus. ㉝ Still later, much of the radioactivity was found in secretion vesicles, little bags which bud off the Golgi and move to the cell membrane and dump their contents outside the cell. ㉞ Here is an electron micrograph of a secretion vesicle pinching off the Golgi apparatus. ㉟ Thus the function of the Golgi apparatus appears to be secretion of cell products, especially proteins.

(36) Some of the vesicles produced by the Golgi apparatus may be lysosomes. Lysosomes are membrane-bound vesicles containing enzymes and other chemicals which are capable of breaking down cellular molecules and structures. Lysosomes are found almost exclusively in animal cells. Under normal conditions, the enzymes within the

lysosomes are inactive, but if the cellular environment changes or the cell is damaged, the contents of the lysosomes may spill out and destroy the cell. Thus, lysosomes destroy cellular debris and make room for repairs to be made. ㊲ Lysosomes may also be important in development. For instance, they are responsible for the breakdown of a tadpole's tail as the tadpole develops into a frog.

㊳ Some cells take in food in a process known as phagocytosis. The cell surrounds a food particle, and a food vesicle in pinched off, forming a membranous bag around the food inside the cell. A lysosome empties its contents into the vesicle to break down the food, and the cell absorbs the products of this breakdown through the membrane. ㊴ White blood cells or "phagocytes" are phagocytizing debris and bacteria in your bloodstream right now.

㊵ Here is what your checklist should look like at this point.

㊶ Plants make their own food; they do it in organelles called chloroplasts, where the energy of sunlight is captured and converted into the chemical bonds of glucose and other organic molecules. ㊷ This process is called photosynthesis.

㊸ The chloroplast is a complex structure, as seen in the diagram and in this electron micrograph. It is surrounded by a double membrane. Inside, there are stacks of membranous pancakes called lamellae or thylakoids. Each stack of lamellae is called a granum, a word which means "grain." The membranes in the stacks are grana lamellae, and those between the stacks are stroma lamellae. Chloroplasts occur in various shapes and sizes. Some plant cells have only one chloroplast each, but most plant cells have several.

㊹ The chloroplast is just one example of a more general type of organelle--the plastid. Besides chloroplasts, there are other kinds of plastids. Chromoplasts contain pigments; storage plastids like this one stockpile starch and other materials.

㊺ Only plants have plastids. But these blue-green algae, which are prokaryotes, have lamellae and perform photosynthesis. The lamellae of blue-green algae and photosynthetic bacteria are not enclosed in plastids and are thought to be derived from the cell membrane.

㊻ Plants make their own food. Animals must get their food from other organisms. In all eukaryotes, food is broken down to release its energy in organelles called mitochondria.

㊼ The mitochondrion consists of an outer membrane and an inner folded membrane. The folds are called cristae. The material between the cristae is called the matrix.

The mitochondrion is the oxygen-using organelle, the organelle which oxidizes food molecules, producing the cells energy molecule--ATP. ㊽ This energy-releasing prpcess is called respiration. A complex array of enzymes and electron-carrying molecules are arranged in the cristae. Other enzymes and reactions are located in the matrix. An average eukaryotic cell may possess from 200 to 10,000 mitochondria. Some prokaryotes have the same energy-producing machinery, but it is attached to the cell membrane or free-floating, rather than packaged in mitochondria.

㊾ Microbodies are small organelles which occur in both plants and animals. Their function is not well-understood, but they seem to play a role in the oxidation and reduction of certain chemicals in the cell and the breakdown of harmful cellular waste products.

㊿ This diagram of a plant cell shows many of the organelles which we have discussed so far. Note the relative sizes and positions of the various organelles.

(51) Tiny protein rods called microtubules are found in many eukaryotic cells. There are a number of microtubules in this picture. Microtubules are long but very

thin. They can be assembled and disassembled very rapidly. Microtubules act as supporting rods for some cells. They may function as guides for cell wall formation in plants. They are also involved in cell movement, as subunits of flagella and cilia (to be discussed in a moment).

(52) This diagram shows the structure of a single microtubule--a cylinder of globular protein subunits, something like a tiny brick chimney.

(53) Animal cells contain curious structures called centrioles, which are made largely of microtubules. The centrioles are little bundles formed of nine groups of three microtubules, seen in cross-section here.

(54) The centrioles act as centers of organization for the spindle apparatus, the array of microtubules which aids in the movement of the chromosomes during cell division. (55) You can see the microtubules radiating out from the centriole in this electron micrograph.

(56) Small hairlike or taillike rods project from the surfaces of many cells. These projections are called cilia or flagella. Flagella and cilia provide propulsion for eukaryotic cells. They act as tails or oars.

(57) You can see the internal structure of several cilia in this cross-section. There are nine pairs of microtubules, with two single microtubules in the center. This is referred to as the "nine plus two" arrangement.

(58) In this cross-section of flagella, you can see that cilia and flagella are essentially identical in structure. Then what's the difference? If a cell has only one or a few of these structures, each is called a flagellum. If a cell is covered by many, each is called a cilium.

Some bacteria also possess structures called flagella, but these are quite different in structure and function from eukaryotic flagella.

(59) Cells break down food, release energy, move, and as a result, they produce wastes. Waste products are not much of a problem to single-celled organisms, like this Amoeba. Their waste products merely diffuse through the cell membrane to the outside.

But larger organisms accumulate lots of wastes. Animals have circulatory and excretory systems to take care of this problem. (60) Most fungi and plants dump their cellular waste products into organelles called vacuoles. A vacuole is merely a large bag made of a single membrane. Wastes and other substances are transported through the membrane and stored inside the vacuole. The vacuole often contains pigments; the color of many flowers is due to accumulations of colored substances in flower cell vacuoles. Expansion of vacuoles is often responsible for plant growth, and the pressure of water stored in vacuoles helps keep plants upright. (61) Many plant cells are mostly large vacuoles surrounded by thin layers of cytoplasm.

(62) A plant, fungus, or prokaryotic cell is surrounded by a rigid cell wall, which protects the cell, (63) prevents the cell from bursting, and gives the cell shape. (64) Plant cell walls are made of cellulose, a carbohydrate which is layed down in crisscrossing networks of fibers. The cellulose is glued together with a filler of other molecules to make a strong but porous structure. Molecules can pass through the wall easily, but the cell membrane is held inside. Note that the cell wall does not replace the cell membrane; it lies outside the cell membrane.

(65) This picture shows living and dead cells in wood. The dead cells contain no cytoplasm; their walls form tubes which carry water through the tree.

(66) Prokaryotes like this bacterium also have cell walls. These walls are similar in function to the cell walls of plants, but they are built of different materials. Nearly all animals lack cell walls, and only a few protozoa have cell walls.

(67) Well, that just about finishes out guided tour of the cell. Our completed cell is quite a complicated structure. Perhaps you would like to turn off the tape for a moment and study this diagram. (68) Here is what your checklist should look like now.

(59) If you would like to test your knowledge of cell structure and function, there is a set of quiz slides at the end of this presentation. After you stop the tape, look at the slides and give the names and functions of the structures indicated. Each quiz slide is followed by an answer slide, so you can check your answers.

(70) The cell is a complex, dynamic living entity. We have learned much about the cell since the microscope and the electron microscope were invented, but there is still much to be learned. New structures are discovered every so often, as techniques for preserving and observing cells are perfected. We are still trying to figure out what the organelles do and how they work.

We are interested in the cell because it is a sort of lowest common denominator of life. Understanding the life of the cell can help us to understand life as a whole.

QUESTIONS

1. Describe the main advantage and disadvantage of the electron microscope as compared to the light microscope.

2. Describe the major differences between procaryotic and eukaryotic cells, and give an example of each kind of cell.

3. An electron micrograph of part of a cell reveals the presence of a cell membrane, cell wall, and ribosomes. This is least likely to be what kind of cell?

4. A cell is treated with a chemical which interferes with microtubule formation. This is likely to disrupt what cell process(es)?

5. Name two structures or organelles that you would expect to find in a eukaryotic cell but not in a prokaryotic cell.

6. Name two structures or organelles that you would expect to find in a plant cell but not in an animal cell.

7. Name two structures or organelles that you would expect to find in an animal cell but not in a plant cell.

8. If a cell contains a higher concentration of dissolved molecules than its liquid environment, sometimes water will move into the cell, a process called osmosis. This water often causes cells to swell and burst. Which cell would be most likely to burst in this situation, a plant or animal cell? Why?

9. Name the organelles where the following processes take place:

   respiration
   protein synthesis
   protein secretion
   photosynthesis
   information storage
   propulsion

10. Which cell would you expect to contain more mitochondria , a muscle cell or a skin cell?

11. In which organelle or structure would you expect to find high concentrations of each of the following substances: DNA, ATP, cellulose, plant pigments.

12. Using a laser beam, a biochemist destroyed the nucleolus of a cell. After about an hour, protein synthesis in the cell stopped. The biochemist knew that no protein is ever made in the nucleolus. Explain the results of his experiment.

13. Some medical researchers believe that the tissue degeneration of old age may be associated with a change in the membranes of lysosomes, making these membranes more likely to rupture accidentally. Explain how this change might be related to ageing.

14. Describe the relationship between the endoplasmic reticulum, Golgi apparatus, secretion vesicles, and the cell membrane.

15. Do you think all plant cells, even root cells, contain chloroplasts? Why?

MOD 124 The Solar System and the Stars

This MOD is intended to be an independent study using the twelve Independent Study Prints found on the shelf in the Resource Center.

OBJECTIVES:

At the completion of this MOD you will be able to:

1. Explain briefly the causes of both the seasons and day and night.
2. Briefly describe the sun as an individual star.
3. Explain why we see different constellations(or groups of stars) at different times of the year.
4. Define eclipses and tides.
5. Explain some of the "hidden meanings" of a few terms, i.e. light year.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Hynek and Apfel, Astronomy One, pp. 234-238 in Chapter 16 and pp. 255-258 in Chapter 21
2. Bash, Astronomy, pp. 12, 13, 15, 16, 17, 18, 51, 56, and 57
3. Navarra and Strahler, Our Planet in Space, second half of Chapter 3, pp. 87-102 in Chapter 5, and p. 181

There is some duplication in the suggested readings, but this is to give different approaches to the materials.

PROCEDURE:

1. Read the sections in the books listed above.
2. Study the prints in the folder.

On Sheets 1 and 2 you will familiarize yourself with the relationships of the earth and the sun, first with respect to the rotation of the earth, and secondly with respect to the revolutionary motions of the earth. Sheet 3 will speak of the planets; sheet 4 describes the sun as an individual object. Prints 5, 6, 7, and 8 discuss the nearest neighbor to earth in space, the moon. Prints 9 and 10 discuss the stars from a standpoint of constellations and the revolution of earth in orbit. Sheet 11 briefly introduces you to the galaxies and sheet 12 mentions the major instrument used by astronomers, the telescope.

3. Answer the questions and do the exercises on the next page.

FINAL ASSESSMENT:

Bring your answers and ideas to the evaluation session and be prepared to discuss them.

Questions and Answers

1. Name all the planets, in increasing distances from the sun.

2. How do you account for day and night?

   How do you account for the seasons?

3. How far away is the moon?
   Name two definite observable occurrences on earth that are caused by the moon.

4. How do the Jovian planets differ from the Terrestrial planets?

5. Name the planets that can be seen with the naked eye.

   Name the last three to be discovered.

6. What is the sun mostly composed of?

   How far away is the sun?

7. Define: Astronomical unit

   Light year

8. Why do we not experience an eclipse of some kind each month?

MOD 125 Evaluating Video-Taped Science Lessons

OBJECTIVES:

1. After creating lesson plans for activities 1 and 2 from ESS, Kitchen Physics, Teacher's Guide, you will compare your proposed teaching strategy with that of a teacher whose science lesson has been video-taped.
2. Given two video-taped science lessons, you will be able to discuss the questions on the following pages.
3. You will be able to compare and/or relate the ESS philosophy with that employed by the teacher in the video-tape sequence.
4. You will be able to compare the teaching strategy in the video-taped lessons with what you consider to be an inquiry style science lesson.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Kitchen Physics, Teacher's Guide
2. Carleton Video-Tape Project, video-tapes #S-004 and #S-005
3. Question set in the attached pages - adpated from the Carleton Video-Tape Project, Northfield, MN
4. Panasonic Cassette Recorder, Model NV-2125.
5. TV monitors

FINAL ASSESSMENT:

See objective above. Bring your completed MOD sheets to the instructor at the time of the final assessment. The assessment of this MOD will be a small group activity with the instructor of your choice for a period of approximately one hour. Be prepared to discuss the questions on the attached sheets.

PROCEDURE:

Step 1

Read pages 1-39 in ESS, Kitchen Physics, Teacher's Guide and create a brief lesson plan for activity 1, "Drops and Heaping," p. 10, and a plan for activity 2, "Bottles and Steams," p. 22. Your plans should contain the following headings:

- Title of Lesson
- Process Objective(s)
- Content Objective(s)
- Pre-lab Activities
- Lab Activities
- Post-lab Activities

Classroom situation

Assume you are working with 5th graders of middle-class background and a class I.Q. range of 100 to 140. You have a maximum time limit of 45 minutes to accomplish your objectives. The children will vacate the room at that time. You are beginning your student teaching.

Step 2

After completing both lesson plans, play back video-tape #S-004 (37 min.) and video-tape #S-005 (45 min.). Do not view the tapes until after your plans are written.

Background Information Concerning Video-Tapes

Woodlake Elementary School is located in Richfield, Minnesota, which is a fairly close-in suburb of Minneapolis. The socio-economic background of most of the students is middle-middle class. Approximately 40% of the students have both parents working. The school does not use ability grouping in assigning classes.

The fifth grade class shown on these tapes consists of 13 boys and 15 girls with an I.Q. range of 100 to 140+. They have not previously met in this room nor with this teacher; they changed rooms and teachers for this course in science. The students are just beginning their study of the first lesson in the "Kitchen Physics" unit prepared by the Elementary Science Study.

In tape S-004, the students are introduced to the "Kitchen Physics" unit and work on investigation 1. Excerpts shown on the tape are from two class periods to show the complete lesson from the pre-lab and lab through the post-lab activities.

Tape S-005 shows the class doing investigation 2, "Bottles and Streams." Time is taken to prepare the room for a rather messy activity.

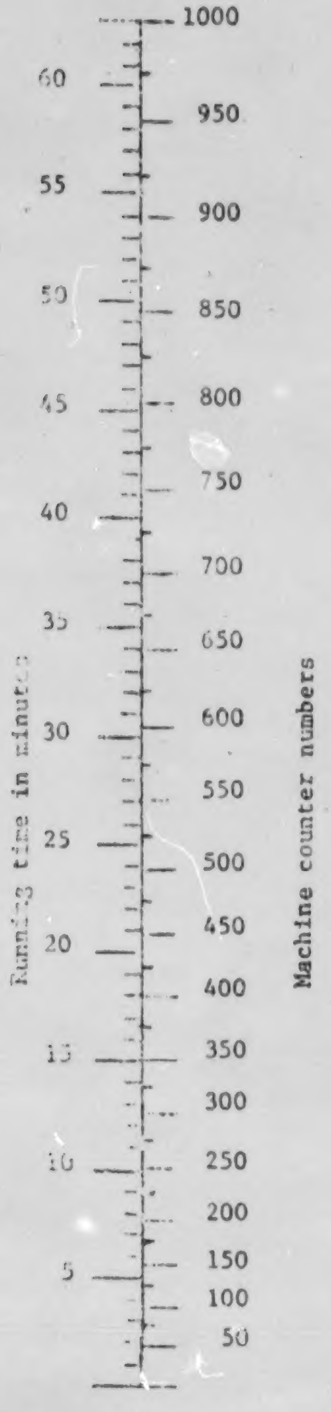
Mr. David Legvold, teacher, was in his eighth year of teaching and had taught materials of the Elementary Science Study curriculum program for three years, at the time this class was taped. He holds an Elementary Education degree and his background in science consisted of approximately twenty-four quarter hours of course work.

Video Guide for Tape #S-004

Elapsed Minutes	(Set counter at zero when volume number appears on the screen.)
	Introduction
2½	The teacher makes some general remarks about the unit and the students begin working on the experiment.
12	The teacher interrupts the class to consider "discoveries" made by the students.
21½	The teacher hands out wax paper and the students begin to "race" their drops.
28½	The students discuss their findings.
34 3/4	The following day, the teacher holds a review of the previous day's activities.
37	The tape ends.

Locator Chart

To be used with the Panasonic cassette recorder.



To use, locate the time of the desired activity (as taken from the video guide) on the left scale. The right scale will then give you the approximate counter number of the desired activity.

Zero your counter at the fade-in of the volume number at the opening of the tape.

Set up the Carlton video-tape #S-004 on either the Sony 3600 or 3650 recorder. Answer the following questions in the space provided or on the back of the MOD sheets. Use the "elapsed time" or the counter numbers (in parentheses) to facilitate reviewing the taped lesson.

Elapsed
Minutes

Start the tape to compare hypothetical teaching strategies devised by viewers with those employed by the teacher shown on this tape.

12 (294) Stop when the video fades while pupils are doing laboratory work. Discuss:

a. How did the teacher's introduction of the unit compare with the way you would have handled it? Do you think the teacher might have given some general clues as to the substantive nature of the material? Why, or why not?

b. What was your reaction to the teacher's starting the experiment by simply stating that he is going to give them some materials and they are to go to work on them? (103)

c. How efficient were the teacher's procedures in passing out the materials? (105) Can you think of alternative procedures?

d. Do you think the teacher gave the pupils sufficient guidance and direction for their work? Were there any safety procedures he might have called to their attention?

Start the tape to view the next section.

21½ (462) Stop at the next video fade, after teacher says, "See what happens." Discuss:

a. How does the teacher use questions to direct the students' attention to the properties of liquids? Should he direct students' observations in this fashion? Why, or why not?

b. How did the teacher help students identify important data? Can you think of other ways he might have done this. Do you think it would be a good idea to give each of the pupils a worksheet to record data in this kind of activity?

c. What is your reaction to the way in which the teacher dealt with the boy who dropped his eye dropper in the bottle of water? Have you noticed any other instances in which the teacher has responded to inappropriate behavior?

Start the tape to view the next section.

28½ (567) Stop at the next video fade, after teacher says, "Just lay it on the table." Discuss:

a. To what extent do pupils follow the suggestion to "race" their drops? What other kinds of activity did you observe? How would you differentiate between inquiry and just "messing around?"

b. The noise level in the classroom has increased considerably throughout the period. If you were the teacher, would you urge the pupils to be quiet? Would you allow as much freedom as this teacher does? How many children do you think are wasting time?

Start the tape to view the next section.

34 3/4 (658) Stop at the next video fade which marks the end of the class period. Discuss:

a. How did the teacher's post-lab activities compare with those you had planned? Was his approach effective? Do you feel his treatment of the data was adequate?

b. Were you satisfied with the teacher's summary that "water is in love with itself?" How would you have summarized the lesson?

c. Generally speaking, how does this teacher handle conflicting opinions?

d. This lesson was approximately forty minutes long. Would you have expected fifth graders to exhibit so long a span of interest? What factors do you think may have influenced their response?

Start the tape to view the next section.

37 Stop at the end of the tape. Discuss:

a. Was this merely a review of the preceding day's finding, or did you feel that the teacher was actually concluding the post-lab discussion at this time? What advantages would you see in his having post-poned the entire post-lab for this day?

b. What is your reaction to the vocabulary used by the teacher in helping pupils review the behavior of the liquids?

c. To what extent do you think this lesson was representative of the ESS philosophy of teaching science?

Video Guide for Tape #S-005

Elapsed Minutes	(Set counter at zero when volume number appears on the screen.)
	Introduction
3	Part I: the teacher and class make preparation for the experiment.
8	The teacher distributes supplies and equipment and the room is reorganized to minimize the mess.
12 3/4	Beginning of Part II: most of the organizing is complete; the students begin to manipulate the equipment and to record data.
25	The teacher summarizes the data gathered on the board.
31½	Students work at plotting the length of the water column against a strip of black paper.
45	The tape ends.

Set up the Carlton video-tape #S-005 on the Panasonic cassette recorder, model nv2125 and again review the tape and answer the following questions.

Elapsed Minutes

Start the tape to view the beginning of the class. Notice the teacher's strategy in passing out equipment and in giving instructions.

12 3/4 (299) Stop at the end of Part I, after teacher says, "You've got to go about your business without any horseplay." Discuss:

a. At the very start of the tape the teacher cautions his students. What kinds of behavior was he attempting to prevent, and what kinds of behavior was he attempting to encourage? Do you think he could have inhibited inquiry by his statement?

b. How does the teacher's introduction to the investigation compare with what you would have done?

c. Was his procedure in getting the pupils ready for work effective and efficient?

d. How natural was the line of questioning that led up to the first pouring activity using the plastic bottles? What would you have done differently?

e. Did the children seem to understand the procedural questions at the end of this segment? Did they know how to use the equipment? Did they have any idea why they were using these items of equipment, or why they were doing what they were doing?

Start the tape to view the beginning of Part II.

25 (512) Stop as the picture fades. Discuss:

a. Do the children seem to know what they are supposed to do, or are they merely having fun playing with the water? Would you have structured this investigation differently?

b. What procedures might reduce the amount of water on surfaces where the children are working?

Start the tape.

31½ (606) Stop at the next video fade. Discuss:

a. By this time it should be obvious that the previous activities were intended as warmups. Was it necessary to be so circumspect? What choices did the teacher have? How might you have planned it? .

b. Do students seem to have any difficulty in taking data? Were they ever told how to record? Would it be more efficient to develop some type of a data sheet to help students organize?

c. Is there any evidence that this portion of the laboratory takes too long? Do the students continue to be interested? Do they continue to work, or do they start to play around?

d. The teacher has chosen to record the data on the board. Does he record all of the data collected? Would it be better to compile a class histogram?

e. What does he attempt to show? Does he ever do it?

f. How does the teacher treat student findings that are not consistent with those of other students?

Start the tape to view the final segment.

45 (790) Stop at the end of the tape. Discuss:

a. This portion of the lesson deals with the cohesiveness of water. Children are attempting to discover some way to measure it. Do you think that the method chosen is the most effective? What choices does the teacher have? What problems do students have?

b. Notice that towards the end of the tape children started to play around. Do you think that the lesson was too long, or that there were too many activities planned for one day? What would you have done?

c. When children become restless what does one do? What did the teacher do?

d. As children became distracted, how did the instructor refocus their attention on the work at hand?

e. Do you think an activity as messy as this one should be attempted in a classroom which doesn't have special laboratory facilities?

f. What is your reaction to the clean-up activities?

g. How do you think the teacher felt about this lesson? What do you think the students learned?

h. How would you evaluate this teacher's rapport with the students? To what do you attribute this?

MOD 126 Developing a Teaching Lesson in Science

This MOD is designed to allow you to develop and refine a lesson utilizing science concepts and processes from one or more of the MODs you have completed and incorporating them into a lesson to be taught to elementary children.

PREREQUISITES: MOD 100, 114, 125, and at least six MODs from among the following: 102, 104, 106, 108, 110, 112, 113, 116, 118, 121, 122, 123, and 124

OBJECTIVES:

1. At the completion of this MOD you should have a complete lesson plan for an elementary class with the following components:
    - A. Title
    - B. Grade level (check with instructor)
    - C. Concepts and/or processes emphasized
    - D. Behavioral objectives
    - E. Materials needed
    - F. Instructional procedures
    - G. Final assessment
2. You should be able to identify the competencies from the accompanying list that you showed greatest strength in and those which need to be improved.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SAPA, Commentary for Teachers
2. Elementary science materials and references in the ISMEP laboratory and SME Resource Center
3. Video-recording and playback equipment
4. Video tapes from the 1977-78 SME 100 class

PROCEDURES:

1. Check with an instructor the grade level for which to prepare the lesson.
2. Study the sections, Behavioral Objectives and Actions Words, from "Behavioral Objectives, Action Words, and Process Hierarchies" in the SAPA Commentary for Teachers (pp. 19-24 in newer edition or pp. 21-26 in older edition).
3. Working with your ISMEP partner, write a plan, in good form (preferable typed), following the outline in OBJECTIVES for a 30-40 minute lesson appropriate for the grade level identified in #1 of this section.
4. Submit a copy of your plan to an instructor for review.
5. Discuss the plan with the instructor, making changes agreed upon by you and the instructor.
6. Revise the plan to be used in the peer-teaching and to be duplicated for the classroom teacher in whose classroom the lesson will be taught.
7. OPTIONAL: View a video tape from the 1977-78 SME 100 peer-teaching file.

8. With four to six ISMEP peers as students, teach the lesson, alternating leading roles with your partners and emphasizing a process-oriented, inquiry style of teaching, while videotaping the lesson. (The lesson will probably require about 20 minutes with peers.)

FINAL ASSESSMENT:

1. Review the competencies on the following page and checkmark those items you think need improvement.
2. Sign up for a 30-40 minute period with an instructor(s).
3. Present a copy of the final lesson plan to be used while viewing the video lesson.
4. View the tape with an instructor(s). The instructor(s) will focus on those competencies that you have checked. Both of you will work on remedial steps to be taken during the science lesson that you subsequently will teach to children.

General Methodology Competencies for the Preservice Teacher of Elementary Science

The prospective elementary school teacher:

1. when given a list of alternatives for teaching science to children, will be able to identify those alternatives that are more conducive to an inquiry style of teaching.

2. when in a science teaching role in the actual classroom, will be able to create situations that incite investigation by the children. The ability to "incite investigation" will be evidenced by the following types of behavior:

   (a) children respond enthusiastically to the teacher's directives.
   (b) children ask, or by their behavior imply, curiosity type questions such as, "what if...?," "how can I make it...?," "if I do this what will happen...?," "let's do this and see what happens...," "don't show me, let me figure it out...!"

3. when in a science teaching role in the actual classroom, will employ divergent questions in initiating a student-centered science investigation.

4. will invite children's participation in an investigation through questioning rather than lecturing.

5. will be able to encourage open-mindedness and discourage impetuous decision-making or generalizing by children.

6. will be able to respect and acknowledge contrary opinions expressed by children when such opinions can be demonstrably based on a logical sequence of thinking.

7. will be able to withhold value judgments of children's answers when lack of expression of such value judgments leads to more discussion.

8. not only permits but encourages discussion among children when an investigation is in progress.

9. will be adept at procuring materials and/or planning situations necessary for "hands on" science.

10. will show evidence of using materials and/or creating situations to help children view natural systems first hand.

11. will emphasize process development and assessment.

12. will recognize that in an inquiry-oriented science lesson, closure implies organization of data and possible redirection rather than formation of premature conclusions.

MOD 127 Teaching Children: Science

PREREQUISITES: MOD 126

OBJECTIVE:

Given a group of four to eight children, you and your ISMEP partner will teach the lesson developed in MOD 126. Each partner will assume the major roles for a portion of the lesson. The lesson will exemplify a process-oriented, "hands-on" inquiry style of science instruction. You should perform according to the criteria listed in MOD 126 on the competency page titled "General Methodology Competencies for the Preservice Teacher of Elementary Science". The lesson may be video-taped.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Plan developed in MOD 126
2. Materials listed in MOD 126
3. "General Methodology Competencies for the Preservice Teacher of Elementary Science" in MOD 126
4. Video Tape Recorder if necessary

FINAL ASSESSMENT:

Each ISMEP team will sign up for a 60-minute time period as soon as possible following the teaching experience. The performance will be evaluated in terms of strengths and weaknesses on the competencies presented in MOD 126.

PROCEDURE:

You and your partner will collectively teach a lesson or lessons emphasizing the process-approach. The lessons will be taught to a group of children at an elementary school location. The particular schools, classrooms, grade levels, and units will be selected after the principals of those schools and the ISMEP staff can arrange mutually agreeable schedules. You will probably do your teaching within the ISMEP scheduled time periods during a 3-week interval toward the latter part of the term. After the scheduling has been accomplished, you will be given options of grade level on a first come - first served basis. IF needed a master schedule will be posted on the ISMEP bulletin board when final arrangements with the principals and teachers have been established.

Flexibility in individual small groups should be built into each lesson. Evaluation of pupil progress will be an integral part of the lesson planning.

In the seminar with the faculty member each team member will give what she thinks are the pros and cons of her individual effort. After this the team members and the instructor will evaluate the progress of the team. Remedial steps will be suggested, individual competencies will be assessed.

Assessment: During each lesson the faculty member will be observing individual activities. He/she will be looking for evidence of the methodology competencies listed in MOD 126 , p. 3 . A value judgment will be made to determine whether or not the individual student has, at this time, succeeded in achieving an acceptable level of competence relative to all of the applicable items on the list.

MOD 128* Soaps and Detergents
Observing, inferring

OBJECTIVES:

Given the materials in the MOD, you will be able to:

1. demonstrate surface tension;
2. investigate how soaps and detergents serve as binding agents;
3. distinguish detergents that do and do not completely dissolve;
4. test detergents for fillers by observing floating;
5. test how pre-soaks and enzymes destroy proteins and carbohydrates.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. The Soap and Detergent Association, Detergents and Environments, 1972 - cassette and slides, in MOD tray.
2. Schmidt and Rockcastle, "Beneath the Suds," Teaching Science with Everyday Things, McGraw-Hill Book Co., 1968, in Resource Center.
3. Soap, detergents, pre-soak and enzyme samples
4. Small jars, razor, oil, cherrios
5. Wilson, Physics - Concepts and Applications, pp 476 - 77

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the activities in this MOD when you report to your instructor.

*MOD 128 was prepared for the Unified Science Curriculum at the College of St. Teresa by Sally McClean, 1971.

PROCEDURE:

General Information

Soap was made nearly 1,000 years ago by boiling tallow and wood ashes, then treating it with salt. One hundred years ago nearly all soap was made at home by boiling fats and oils with alkali in a process called saponification. Then salt is added. The salt makes the soap rise to the top while the salt solution and excess alkali sinks to the bottom and is drawn off. This process is repeated five or six times. More water and alkali are added until the last bit of fat is saponified. Today soap is churned while perfumes and coloring are added. For floating soap, more churning is done. Air is beaten into liquid soap to make it lighter.

Hot melted soap is then made into bars or granules. Granules are made by grinding dried soap, placing them in a 75-foot tower, spraying with liquid, and drying by blasts of heated air as they fall. Particles of dried soap are then ready for packaging.

Soap gives water cleansing and penetrating properties when it is dissolved in a liquid. This is a physical reaction, not a chemical one. Soap must be soluble in order to adsorb, or to collect dissolved matter on the surface of a solid. Additional agitation or rubbing is needed to release or break adsorptive bonds between particles and fibers.

Activities:

1. To demonstrate surface tension.
Water has surface tension which makes it behave as though it were covered with a thin elastic film. Surface tension prohibits water from getting in and around an object and its small particles of dirt.

Fill a glass with water. Carefully place a razor blade on top of the water. Can you make it float? Wipe the blade dry and try it again.

Remove the blade. Stir a teaspoon of liquid soap into the water. After the water becomes calm, place the blade on top of the water. Does the razor blade float? Try this several times before you come to any conclusion.

Did the soap have any effect on the surface tension of the water? If so, what?

2. To investigate how detergents and soaps serve as bonding agents.
Soaps have a chain of atoms, part are water repelling and part are water attracting. The water-repellant end dissolves in grease and oil. The other end dissolves in water. Soaps serve as bonding agents between water and dirt to draw them into the water and to hold them in suspension. When the droplets are small enough, they do not stick to hands and dishes, but work away with the water.

Use two liquids that do not mix, such as oil and water, and a small amount of detergent. Fill a jar 2/3 full of water. Add 10 to 12 drops of oil with a dropper. Does the oil float or sink, or does some float and some sink?

Force some of the oil underwater. What happens to it?

Stir the oil. Does it mix with water? How do you define mix?

Cover the jar. Then shake the oil and water and let it stand. What happens to the droplets? Can you tease them together?

Dip a toothpick into a jar of liquid detergent. Touch it to the center of the water. What happens at the oil and water surface?

Cover the jar. Shake the oil and water. Hold the jar up to the light and observe the contents with a magnifier if possible. Are there more or fewer drops of oil than before? Are they larger or smaller?

Add another small amount of detergent. Shake the mixture. What change do you observe in the number and size of the oil droplets?

Did your investigation verify that the size of the oil or grease droplet is affected by soap?

Aspects of Pollution

Many detergents are advertised to be biodegradable. Biodegradability is the property whereby a detergent is broken down by living organisms in a water treatment or sewage system in a short period such as 72 hours. Thus the detergent can not harm water or animals, cause "heads" on our lakes and streams, or pollute our drinking water supply. Most detergents now used are biodegradable.

Pollution is often traced to phosphates needed in detergents to make clothes white. 100% phosphates act as fertilizers. In water they cause a great growth of algae which uses up so much oxygen that fish die. Algae tends to make a swamp area.

If phosphates are entering natural waterways at all, detergents and soaps would be only 15% of all the phosphate found. Most phosphates would originate from manure from pastures, inorganic farm fertilizer and factory waste. It is not satisfactorily proven that phosphates from soap are in water, but no more phosphates than necessary should be used. Most detergents now on the market contain many more phosphates than necessary.

Although phosphates from soap have not been scientifically proven to be a pollution problem, the public is convinced they are. So soap manufacturers replaced phosphates in soap with N.T.A., table salt, washing soda, and borax. These products may cause more problems than phosphates.

N.T.A. (Nitrilotriacetic acid) whitens and is biodegradable, yet its metal ions (mercury, lead, iron) leech into drinking water. These are poisonous products, so the government took them off the market.

Table salt whitens and is a water softener, yet it has no cleaning power. It causes abrasive action on clothes just as salt does to a car.

Washing soda and borax, if used to large extent in America, will turn our fresh water into salt water. Salt does not disintegrate. These materials are hard on washing machine parts and clothes.

Popular opinion is so strong that in Indiana and Chicago the use of phosphates is forbidden. If water is very soft and very hot water is used, the clothes stay white without phosphates.

High foam from soaps results in the accumulation of large volumes of unmanageable foam. Problems from foam are severe in Britain. Low foaming action soap or detergent more susceptible to bacterial attack during sewage treatment is a remedy to foam.

3. To distinguidh detergents that do and do not dissolve completely.
To be effective a soap must dissolve. A cloudy mixture shows that some of the detergent is not dissolving. Many detergents contain phosphates which are used as softeners and whiteners. Detergents which are biodegradable are broken down by living organisms within a short period in a water treatment or sewage system. Most detergents marketed today use fillers which are non-cleaning substances as bleached sawdust, peanut hulls or groundup paper. The active detergent molecules may comprise as low as 30% of the ingredients. Thus, the majority of the product consists of material which is water insoluble and essentially not biodegradable.

Fill four quart bottles about 3/4 full of cold water. Place ¼ cup of four sample detergents in separate bottles. Label the sample with the name of the detergent. Stir each one with separate spoons for an equal time. After a few minutes observe what happened. Do any of the samples show undissolved material that you can see? Which ones? Record your observations.

Sample A

Sample B

Sample C

Sample D

Do any of the samples show evidence of filler? Which ones?

4. To test detergents for fillers by observing floating.
Put a teaspoon of one of the sample detergents into a small jar and fill it 3/4 full of water. Note whether the detergent initially floats or sinks to the bottom of the solution. If it floats initially the detergent probably contains filler. Record your observations. Then shake the jar until the detergent is dissolved to test for cloudiness indicating the presence of fillers.

Sample A

Sample B

Sample C

Sample D

5. To test pre-soaks and enzymes in destroying carbohydrates and proteins.
Pre-soaks contain both detergent material and enzymes. Enzymes in laundry products refer to the complicated molecules which aid in decomposing a stain molecule. Enzymes selectively digest carbohydrates and proteins. They remove stains by destroying or breaking down stains of carbohydrate or protein origin, such as chocolate, blood, perspiration, grass stain, fruit and vegetable stains, coffee, tea, gravy and catsup. Enzymes can not harm clothing since the fibers in materials are not protein. However, persons allergic to enzymes may react from them with skin problems or itching.

Place a teaspoon of three sample enzyme pre-soaks in separate jars. Fill the jars one-half full of very hot water. Add ten cheerios to the jar and cover it. Shake and wait an hour. Since cheerios are about 85% carbohydrate and protein, an enzyme pre-soak should break down most of them. Record the effectiveness of the enzyme pre-soak.

Sample X

Sample Y

Sample Z

Let the cheerios soak in the samples for 24 hours and record your observations.

Sample X

Sample Y

Sample Z

MOD 129 Float or Sink?
Predicting, interpreting data

OBJECTIVES:

1. Given the materials in the MOD tray and having completed the attached activities, you will be able verbally to state the relationship between specific gravity and buoyancy in regard to the ability of an object to either sink or float.
2. After having completed the attached activities, and having been given density tables, you will be able to predict whether various objects will sink or float in alcohol, gasoline, mercury, or sea water.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, _Clay Boats_, Teacher's Guide
2. ESS, _Sink or Float_, Teacher's Guide
3. SAPA, 103, Density.

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

General Information

Once upon a long time ago, a man named Archimedes (287-212 B.C.) was reclining in his bathtub pondering why certain objects sink while others float. He had been perplexed with this problem for some time and, according to popular legend, while in the tub the idea of buoyancy came to him. He was so excited that he quickly jumped out of the tub and ran out into the street yelling "Eureka, I have found it!" (Liberal translation) Needless to say, Archimedes was more excited about discovering the principle of buoyancy than you probably are going to be, but do not underestimate the excitability of children when given the same opportunity. ESS has a unit on the topic of buoyancy titled Sink or Float. Also ESS has another related booklet entitled Clay Boats with many inquiry lesson ideas. You may use these booklets as references to apply this MOD to the elementary school situation.

At the completion of this MOD you should understand the meaning of the terms density and specific gravity, and you should also be able to predict whether an object will sink or float given its density and the density of a fluid such as water.

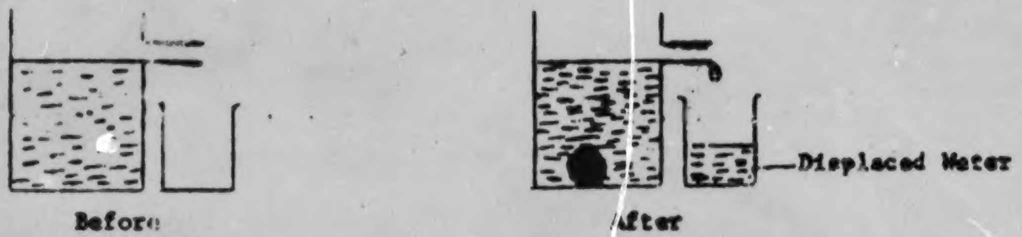
Density is defined as the relationship of the weight of an object to its volume. It is expressed as D = W/V. Therefore, the units of density would be such as lbs./ft.^{3} (pounds per cubic feet), g./cm.^{3}, g./ml., etc. Specific gravity is defined as the ratio of the weight of an object to the weight of an equal volume of water. For example, assume a cubic foot of metal "X" weighs 312 lbs. Since a cubic foot of water weighs 62.4 lbs. the specific gravity of metal "X" would be 312 lbs./62.4 lbs. or 5. Or a cubic foot of wood "X" weighs 31.2 lbs., so the specific gravity of wood "X" would be 31.2lbs./62.4 lbs. or .5.

Activities

1. Find the density and specific gravity of a piece of clay. Roll a piece of clay about the size of a golf ball. Re-wrap the block of clay carefully to keep it pliable. Put this ball of clay into a bucket of water. Does it sink or float? ___________

2. Remove the clay from the water and measure its weight in grams. Record this weight. ____________

3. Find and record the volume of the clay in ml. by using the overflow can method (as shown below).____________



Before After

4. Weigh the displaced water. ____________

5. Find the specific gravity of clay. ____________
Would a different volume of clay show approximately the same specific gravity? ____________ If you are in doubt, find out by testing.

6. Take the same piece of clay which originally sank. See if you can reshape it in order to make it float. Your clay boat will have to be small enough to sit in the overflow can without touching the sides. Also be sure you have the same quantity of clay that you had in activity 1 by weighing it.

7. After you shape the clay boat to make it float, place it in the overflow can to see how much water it displaces. Collect the overflow water in a graduated cylinder. Record the volume in ml. ____________

8. Weigh this quantity of water by: a) placing a small, clear plastic container on each platform of the balance scale; b) balancing the scale at the zero point; and c) pouring the overflow water into the plastic container on the left side of the scale. Record the weight in g. ____________ The weight of displaced water in g. whould approximately equal the volume of water in ml.

9. Compare the weight of the displaced water with the weight of the clay. Is it within a gram or approximately the same? ____________ To what might the discrepancy of the two weights be attributed?

10. Now very carefully add just enough sinkers (small, grey weights) to make your boat sink. As you do this, collect the overflow water in a graduated cylinder. This part works better if top surface of boat is level all across.
How many sinkers make your boat sink? ____________
How much more displaced water overflowed? ____________ml.
How much weight does this number of sinkers represent? ____________g.

11. Add the weight of the boat to the weight of the sinkers.
Total weight = ____________g.

12. Add the weight of the water displaced by the floating, empty boat (activity 8) to the weight of the displaced water after the boat sank (activity 10). Total weight = ____________g.

13. According to the theory of buoyancy, activities 11 and 12 should show equal weight. Are the weights within 2 grams or similar? Or are they different by more than 2 grams? ____________ The important part of this activity is to critically examine possible factors that lead to discrepancies. States these possible factors below.

14. If you can answer the following problems correctly, you are beginning to understand the principles of buoyancy. The answers to the problems are on the last page.

A. Find the density (in lbs./ft.^{3}) of a block of wood which is 3 ft. x 2 ft. x 1 ft. and weighs 27.3 lbs.
B. Find the specific gravity of a piece of steel 3 cm. x 2 cm. x 10 cm. if it weighs 560 g. The density of water is 1 g. per cc.
C. A block of ice has a density of 57.2 lbs./ft.^{3}. What percentage of its volume would be below water? Water density is 62.4 lbs./ft.^{3}.

Information for activity 15

Density of Various Solids at Room Temperature in Pounds/cubic foot

	Substance	Pounds/cubic foot
1.	Butter	53-54
2.	Charcoal (oak)	35
3	Cork	14-16
4.	Rock Salt	136
5.	Gelatin	79
6.	Ebony Wood	69-83
7.	Cedar Wood	30-35
8.	Birch Wood	32-48
9.	Starch	95
10.	Resin	67

Density of Various Liquids at Prescribed Temperatures

	Liquid	Pounds/cubic foot
1.	Alcohol, methyl (20°C)	49.4
2.	Gasoline (0°C)	41.0-43
3.	Mercury (0°C)	849.0
4.	Sea Water (15°C)	63.99

15. Using the preceding tables complete the following table by writing F (float) or S (sink). Assume each solid substance is in a block form 1 ft. x 1 ft. x 1 ft. The first example is completed.

	Solid	Alcohol	Gasoline	Mercury	Sea Water
A.	Butter	S	S	F	F
B.	Charcoal (oak)				
C.	Cork				
D.	Gelatin				
E.	Rock Salt				
F.	Ebony Wood				
G.	Cedar Wood				
H.	Birch Wood				
I.	Starch				
J.	Resin				

Answers for activity 14: A. 4.55 lbs/ft^3; B. 9.33 g/cm^3; C. 91%

MOD 130 Stimuli and Responses
Defining operationally

OBJECTIVES:

1. Having studied the pages of this MOD, you will be able to discuss factors involved in plant growth - cell elongation, auxins, terminal buds, axillary buds, and internodes.
2. Having studied the pages of this MOD, and having completed the experiment, you will be able to discuss relationship that exists between cell elongation, gravity, and auxin concentration in stems and roots.
3. Having completed the experiment, you will be able to show the instructor the germinated seed with roots and stems and point out the position of the seed during any one part of the growth period.
4. Having completed the experiment, you will be able to tell approximately the amount of stem or root elongation during any one position time, without having measured the parts during the actual growing period.

Optional:

5. After designing an experiment to show that plant stems grow toward a light source, you will be able to explain how light affects auxin distribution in a stem.

NSTRUCTIONAL REFERENCES & MATERIALS:

1. This MOD, pp. 2-5
2. SAPA 102, Plants in Light
3. General botany references
4. Materials in the MOD tray
5. SCIS, Environments Teacher's Guide,"Plant Responses to Light".

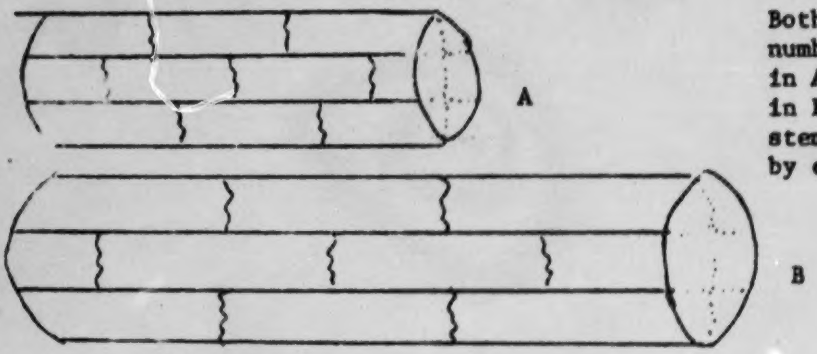
FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

General Information

Plants, when growing, send their stems up and their roots down. Answers or explanations of "why" they grow this way are not as clear as they might be. Plant stems and roots accomplish growth, after certain developmental stages, primarily by cell elongation. For example, if you were to examine a growing bean plant and to measure the distance on a stem between internodes and then to measure the same part of the plant again the next week you would find that the distance between the internodes increased. The net result, of course, would be that the plant increased in height. The elongation between the internodes or growth occurred, not because the plant placed more cells between the internodes, but because the plant elongated the cells that were already there. This is shown in the following diagram.

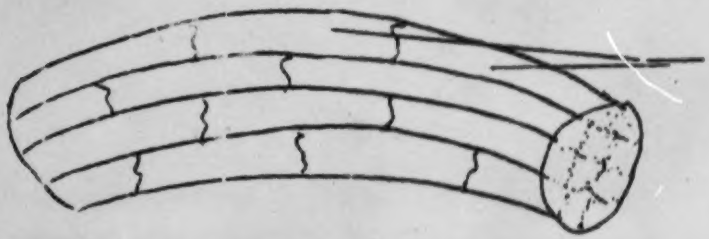


Both stems have the same number of cells. The cells in A are smaller than those in B. Stem B is longer than stem A. Growth takes place by elongation of cells.

Growth rate or cell elongation rate in plants is controlled by growth regulators called plant hormones or auxins. The precise manner in which auxins work is not known. There are several theories which propose complicated mechanisms. However, one assumption can be made and used to explain partially why stems grow up and roots grow down.

As for many chemical reactions, accept that the more chemical the more or faster the influence on a mechanism. Similarly, the more auxin a cell receives the faster it should elongate.

Look at the above drawing to notice that both drawings of the portion of the stem are straight. This type of straight growth is possible only if all the cells in the stem elongated at the same rate and to the same degree. If they do not, the stem would bend to one side or the other as shown below.



Cells on bottom elongated more cause the stem to bend upward

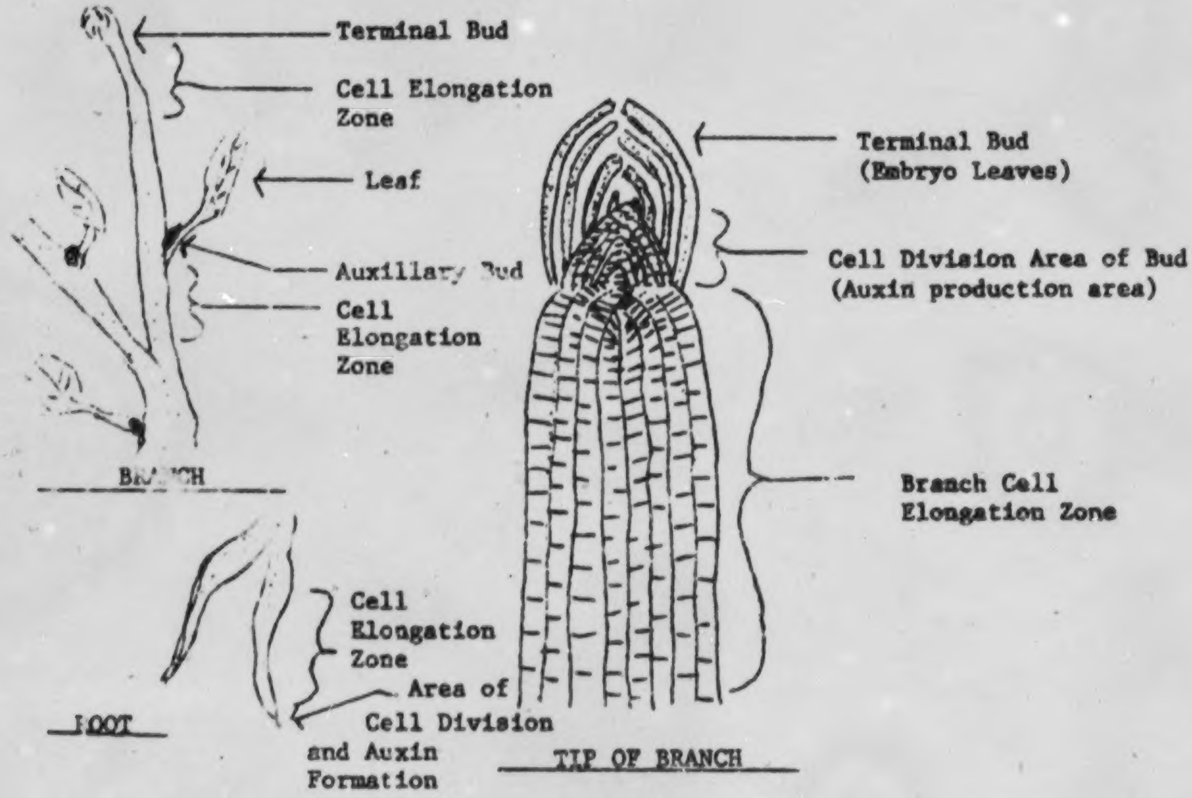
(diagram is upside down)

If you measure the length of the cells, you would find that the cells on the convex (upper) surface are longer than those on the concave (lower) surface. This shows that the longer cells received more auxin than did the shorter cells during the growth period.

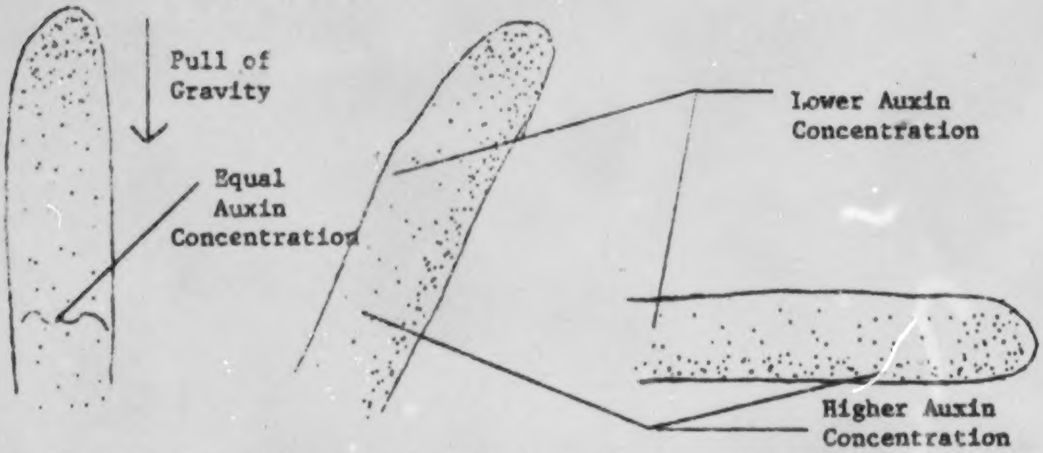
With a scientific habit of inquiry, by now you should have considered the question "Why or how did some cells get more auxins?" Try to figure out an answer before you read further in this MOD.

You may have an idea that light and/or gravity could be influencing factors. Light could influence stems, but what about roots which are underground "stems" and are not usually exposed to light. How could gravity affect the distribution or concentration of auxins in different parts of the plant? Knowing where auxin is produced and how it is transported helps to answer this question.

If you examine a stem of a plant you find that there are buds located at several places on the branch. Each tip of a branch has a terminal bud. Buds are also found in the axil of each leaf where the petiole (stem) of the leaf attaches to the branch. It is the terminal bud that plays a leading role in plant growth. First, the bud produces the cells that form the branch, and then it produces substances that control the growth or elongation of cells. In roots there are no true buds, but the tip of the root or the tips of the root branches serve to produce new cells by cell division and to regulate cell elongation by secreting growth regulating chemicals. The following diagrams illustrate the growth of branches and roots.

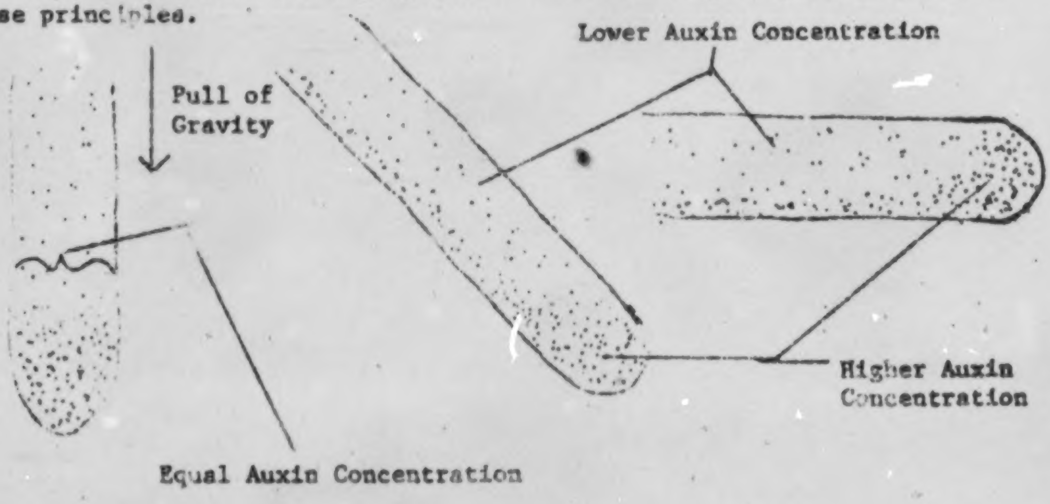

Terminal Bud
Cell Elongation Zone
Leaf
Auxillary Bud
Cell Elongation Zone
BRANCH
Terminal Bud (Embryo Leaves)
Cell Division Area of Bud (Auxin production area)
Branch Cell Elongation Zone
Cell Elongation Zone
Area of Cell Division and Auxin Formation
ROOT
TIP OF BRANCH

Apply the following rules to the tips (buds) of the main branch of the root and stem. If auxins are produced evenly by all parts of the buds and if these auxins are distributed evenly downwards in the stem and upwards in the root, then all cells should receive approximately equal amounts of the auxins. Assume that gravity effects the movement of the auxins, then gravity helps to move auxins down in the stem and hinders auxin movement in the roots. If the stems are not directed straight up then gravity will not serve as a means for helping or hindering the movement of the auxins equally in all parts of the stem. The following illustration demonstrates this principle.


Pull of Gravity
Equal Auxin Concentration
Lower Auxin Concentration
Higher Auxin Concentration

Parts of the stem which have the highest auxin concentrations should have the most rapid stem elongation. In drawings B and C the stems would bend upward from the tip, that is, stems tend to grow up or straight in opposition to the force of gravity.

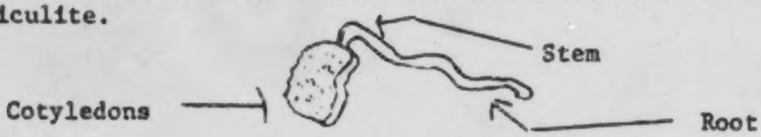
The same principle can be applied to root growth, but it is necessary to stipulate one additional variable. Cell elongation in roots requires very low concentrations of auxins for optimal growth, or roots would be described as growing "up," rather than "down." Concentrations higher than optimal would actually inhibit root cell elongation. The following diagrams illustrate these principles.


Lower Auxin Concentration
Pull of Gravity
Higher Auxin Concentration
Equal Auxin Concentration

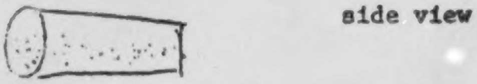
Activities:

Have four seeds in four cups--two experimental (rotated) and two control (not rotated).

Obtain a mung bean seed from the MOD tray. Germinate between wet paper towels in a nine inch culture vessel, cover the vessel to retain moisture. A seed should be selected that has a root not more than 1 cm. long. See diagram below. Observe the seed to note that basically it consists of two parts. The bean seed proper contains two cotyledons attached to a short stem area and an elongated root. Note where the root begins at the bend about ½ cm. from the seed itself. Make an ink mark with a ball point pen at the bend so that later you can tell where the stem ends and the root begins. Do not let the germinated seed dry out. Keep it between two wet towels while you are preparing the styrofoam cup and vermiculite.

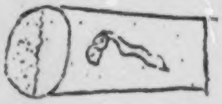


2. Obtain a styrofoam cup and fill it one-half full of moist vermiculite. Do this by placing the cup on its side and filling it one-half full of vermiculite.



With your fingers or a wooden blade press the vermiculite to a medium firmness.

3. Place the germinated seed on the vermiculite so the seed part is in front and the root points to the bottom of the cup.



4. Cover the germinated seed with vermiculite by carefully filling the rest of the cup. Press firm.

5. Place a piece of saran rap over the open end of the cup and put a rubber band around the cup to hold the saran rap in place

6. When you complete these preparations, this is zero hour. Place the cup in any position except the normal upright position for a period of 24 hours.

7. After 24 hours change the position of the cup by 90° in any direction. Change the position of the cup until it has been in 5 positions for a period of 24 hours in each position.

Caution: Simple rotation of the cup in position so that the same side of the cup is up all the time is not an adequate change of position.

8. After the 5th position remove the seedling from the vermiculite. Place it in a baby food jar containing 50% alcohol and present to your instructor during your evaluation. Do not let the seedling dry out.

MOD 131 Life Cycles (SCIS)
Observing, communicating, defining operationally

OBJECTIVES:

1. Given the film loops:
   a. ESS, Frog Egg I, First Cell Division to Early Neural Fold;
   b. ESS, Frog Egg II, Development of the Body Regions;
   c. ESS, Frog Egg III, Continued Development to Hatching;
   d. And the film, Development and Differentiation;

   you will be able to define operationally the various stages of frog egg development that are pointed out on the film loop boxes.
2. You will make day by day observations of the stages of development from frog eggs to tadpoles.
3. You will keep a daily record of changes seen in frog embryology in size, shape, form and activity.
4. You will design your own format for recording observations and data.
5. You will be able to apply the following concepts to everyday situations other than the examples in this MOD.
   a. growth
   b. life cycle
   c. generation
   d. plant and animal
   e. development
   f. genetic identity
   g. biotic potential
   h. metamorphosis

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Life Cycles, Teacher's Guide
2. In the MOD tray, Filmloop, Frog Egg I
3. In the MOD tray, Filmloop, Frog Egg II (All filmloops in Resource Center)
4. In the MOD tray, Filmloop, Frog Egg III
5. ESS, Eggs and Tadpoles, Teacher's Guide
6. General biology references giving information on frog embryology
7. Aquarium with developing frog eggs, hand lens, microscope

FINAL ASSESSMENT:

1. On the film loops be prepared to recognize the various stages of frog development that are pointed out on the film loop boxes.
2. Present your recorded observations and data to the instructor and be ready to discuss your data.
3. See objective 5.

PROCEDURE:

1 View film loops Frog Egg, I, II, and III on frog development and study the stages of frog egg development that are pointed out on the film loop boxes.
2. View the film Development and Differentiation.
3. Read SCIS, Life Cycles, Teacher's Guide, "Frogs," pp. 50-54.
4. Observe the stages of development from frog eggs to tadpoles by making day to day observations. Keep a daily record of changes of the development in frog embryology in size, shape, form, and activity. Use meaningful, descriptive terms in your recorded data.

MOD 32 The Chemistry of Life - Self Instructional Module

OBJECTIVES

1. Interpret and correctly use these terms: organic compound, polymer, polymerization, covalent bond, hydrogen bond, ionic bond, isomer, polar, non-polar, hydrophobic, hydrophilic, functional group, acid, base, condensation, hydrolysis.
2. Describe and identify the kinds of chemical bonds most often found in biological molecules.
3. Given diagrams of two molecules, state whether they are isomers.
4. Identify and sketch these four functional groups, and briefly outline the chemical behavior of each: carbonyl, carboxyl, amino, hydroxyl.
5. State the number of bonds usually arranged around the nucleus of each of the following atoms as they occur in biological molecules: C, H, O, N, P, S.
6. Given a diagram of a molecule, state whether it is likely to dissolve in water and why.
7. Illustrate and identify a hydrolysis and a condensation reaction, and explain how these reactions are related to polymerization.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on chemistry of life.
3. Biology Media instructional materials.
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

INTRODUCTION:

Cells are so tiny that their working parts can be nothing but molecules. These molecules are built of a few common elements that are combined according to a few simple rules to give a few types of compounds. If you learn these elements, rules, and compounds, you will have solid base for exploring the life of the cell. The objectives on the previous page summarize the essential points you should master.

OUTLINE:

I. Introduction
    1. early beliefs
    2. organic chemistry and biochemistry
    3. composition of the cell
    4. major classes of compounds
II. Main concepts of biological chemistry
    1. carbon backbones
    2. polymer structure
    3. atoms from characteristic numbers of bonds
        a. carbon
            1) electrons
            2) three-dimensional structure
        b. oxygen
        c. hydrogen
        d. nitrogen
        e. phosphorus
        f. sulfur
    4. arrangement of atoms in molecule is important
        a. sugar isomers
        b. mirror-image isomers
        c. diagramming structures
    5. kinds of chemical bonds
        a. covalent bonds
            1) single bonds
            2) double bonds
    6. functional groups
        a. general description
        b. carbonyl group
        c. amino group
            1) structure
            2) accepts protons
        d. carboxyl group
            1) structure
            2) donates protons
            3) amino acid
        e. phosphate group
        f. hydroxyl group
            1) structure and function
            2) hydrolysis reaction
            3) condensation reaction
            4) other condensation and hydrolysis reactions
III. Review

① The Chemistry of Life

② It was once believed that living things were imbued with a kind of "vital force" which made them alive. It does seem that the chemical activity of living systems is mysteriously more complex and diverse than that of non-living systems. It was thought that certain chemicals--"organic compounds" such as sugars,--could only be produced by living organisms.

③ In 1826, Friedrich Wohler, a German chemist, succeeded in making an organic compound in the laboratory, without any help from the vital force. ④ The compound he synthesized was urea--a simple molecule containing carbon, hydrogen, nitrogen and oxygen. Wohler's discovery opened the door to the study of the chemistry of living organisms. We can learn much about the structure and function of organisms by studying their chemistry.

⑤ Urea and other organic chemicals which stymied the chemists of Wohler's time are compounds which contain carbon. Organic chemistry is the study of carbon compounds. Biochemistry is the study of the chemical reactions which occur in living organisms--most of these reactions involve organic compounds. This module outlines several general, basic principles of organic chemistry, and also a little biochemistry. In order to understand this module, you should have some background in basic inorganic chemistry. You should have some fanimiarity with the structure of atoms and simple chemical reactions. Most biology textscontain review chapters on chemistry, if you think you need to brush up.

⑥ The chemistry of life on earth is the chemistry of water and carbon. The average cell is about 70% water and 30% other substances. ⑦ Of these substances, 95% are carbon-containing compounds. There are four major types of large organic molecules and about 100 different types of small organic molecules in a cell. (The remaining 5% of the "other substances" are mainly minerals, such as salt.)

⑧ As I said earlier, the large organic molecules can be grouped into four major classes; these were shown on the title slide for this module--carbohydrates, lipids, proteins and nucleic acids. I would like to use these molecules to illustrate six major concepts of biological chemistry. ⑨ Here is a list of these concepts; you needn't write them down at this point; I just want you to know where we are headed.

⑩ 1. First--The basic structure of most organic molecules is a chain of carbon atoms. We can say that such a molecule possesses a carbon "backbone" or "skeleton". This is a carbohydrate molecule. It is starch, such as we might find in a potato. Its structure is basically a repeating chain of sugar rings which are composed mainly of carbon. ⑪ In the backbone of the protein molecule, carbon alternates with nitrogen--NCC,NCC, etc.

⑫ 2. The second point I would like to make may already be apparent to you. Most organic molecules are repeating chains of smaller, simpler building blocks. The starch molecule is a chain of identical sugar molecules. ⑬ The subunits of the nucleic acid molecule are a bit more complex, but the molecule is nevertheless a chain of the complex subunits. ⑭ A molecule which is built of similar, repeating subunits is called a "polymer"--a word which comes from "poly"--"many" and "mer"--"part"; "many" "parts". Starch, nucleic acids, and proteins are polymers.

⑮ The process of making polymers is called "polymerization". We will have a bit more to say about polymerization later.

⑯ 3. Here's the third point: Carbon and the other atoms found in organic molecules each form characteristic numbers of chemical bonds with other atoms, depending on the electron structure of the atoms involved.

The other elements--besides carbon--are mainly oxygen, nitrogen, hydrogen, phosphorus and sulfur. ⑰ Carbon characteristically forms four bonds with other atoms. ⑱ It possesses four electrons in its outer orbital, the orbital which interacts with other atoms. The carbon atom needs eight electrons to complete this orbital. ⑲ It shares electrons with other atoms to complete its set of eight. Suffice it to say that because of its electronic structure, the carbon atom usually forms four bonds with other atoms.

⑳ The four bonds formed by the carbon atom are directed in space toward the four corners of an imaginary tetrahedron, a sort of four-cornered pyramid. This can be seen in a model, with a black ball representing the carbon nucleus and springs, representing bonds, directed tetrahedrally. ㉑ This is a model of a sugar subunit of starch. On a flat piece of paper, it is difficult to show this three-dimensional structure. Try to keep in mind that diagrams of molecules are distortions of reality.

㉒ In organic molecules, oxygen atoms tend to form two bonds--as seen in the starch molecule, ㉓ and in the protein, where an oxygen atom is connected to a carbon by a double bond. ㉔ Hydrogen can form a strong bond with only one other atom. ㉕ Nitrogen tends to form three bonds. ㉖ Phosphorus forms five bonds, by-and-large, and ㉗ sulfur, like oxygen, forms two bonds. We will return to chemical bonds in a moment.

㉘ 4. The properties of an organic molecule depend not only on the relative numbers of atoms in the molecule, but also on the specific arrangement of the atoms. For instance, these two sugars have the same formula-- $C_6H_{12}O_6$--but their structures are different; note the OH group on the left--it points downward in the glucose molecule and upward in the galactose molecule. This slight difference in structure gives the two compounds completely different properties. They are different in melting point, sweetness, and serve different functions in the metabolism of the cell. ㉙ Molecules like glucose and galactose which have the same chemical formula but different structures are called isomers.

㉚ Even two molecules which are mirror images of each other, like right and left-handed gloves, can have very different properties from the point of view of the cell. These mirror-image molecules are also isomers.

Thus, the arrangement of atoms in a molecule is important. In fact, many reactions in the cell are rearrangements. The fact that the arrangement of atoms in a molecule makes a difference makes it necessary to draw out structural formulas when discussing most compounds.

㉛ 5. What kinds of chemical bonds are found in organic molecules? In most organic molecules, most atoms are held together by the sharing of electrons. ㉜ In the long hydrocarbon chain at one end of this fatty acid--a kind of lipid--most carbon atoms share four outer electrons with four other atoms, carbons and hydrogens. Each carbon atom shares its four outer electrons and four electrons from its neighbors--giving it eight outer orbital electrons, a complete set. This sharing of electrons holds the atoms together. ㉞ A bond resulting from electron sharing is called a "covalent bond". The bonds we have looked at so far result from sharing one pair of electrons--they are single bonds. ㉟ Sometimes two atoms are held together by two pairs of electrons; this forms another kind of covalent bond--a double bond. Most bonds in organic molecules are covalent bonds.

㊱ In a bond between two carbon atoms, the electrons are shared more-or-less evenly between the two carbons. ㊲ In a bond between two different kinds of atoms-- say, between carbon and oxygen--sometimes the electrons are unevenly shared. Some atoms simply attract electrons more strongly than others. The tendency of an atom to draw electrons is called "electronegativity". Oxygen attracts electrons more strongly than carbon. Oxygen is more electronegative than carbon.

㊳ In a molecule, the more electronegative atoms pull the electrons toward themselves, away from the other atoms. For instance, in this section of a nucleic acid molecule, the nitrogen atom gets to use the electrons more often than its neighboring hydrogen. Nitrogen is more electronegative than hydrogen. ㊴ Since the nitrogen hogs the negatively-charged electrons, this part of the molecule has a slight negative charge. More importantly, in this case, the hydrogen is left with a slight positive charge. This part of the molecule--the N and the H--is said to be "polar"; it has a positive and negative pole. ㊵ The slightly positive hydrogen may be attracted to a part of a molecule with a slight negative charge, for instance, this highly electronegative oxygen atom. This attraction is called a "hydrogen bond". Hydrogen bonds are relatively weak--about 1/16 as strong as the average covalent bond--but they are very important in the structure of biological molecules, particularly proteins and nucleic acids.

㊶ Polarity and hydrogen bonding are also related to the solubility of molecules--the kinds of substances in which they will or will not dissolve. We'll talk about solubility for a moment, then return to bonding.

㊷ Water molecules are polar; they hydrogen bond with one another. Other polar or charged molecules, ㊸ like urea for instance, dissolve in water because they fit in with the water molecules; the water molecules can hydrogen-bond with the urea molecules. I should point out here that the urea molecules do not fall apart when they dissolve in water; they merely mix with water. Many students get the mistaken idea that dissolving means falling apart. When one substance is not disrupted. The molecules mix--they intermingle.

㊹ Unlike urea, lipid molecules are non-polar; the lipid molecules do not contain long hydrocarbon chains in which the carbon and hydrogen atoms share electrons more-or-less evenly. The lipid molecules cannot form hydrogen bonds with the water molecules and thus cannot dissolve in water. Oils and fats are lipids. They are non-polar. It's an old maxim that oil and water do not mix. However, oil and gasoline do mix. Gasoline, like oil, consists of non-polar molecules. ㊺ A general rule is: "Like dissolves like". Polar compounds dissolve in polar compounds. Non-polar solutes dissolve non-polar solvents.

There is some terminology that goes along with polarity and solubility that you should get. ㊻ Polar substances, such as salts, urea, and sugars, which dissolve in water, are sometimes called "hydrophilic" compounds. Hydrophilic means "likes water". Non-polar substances like fats, waxes, and oils, which do not mix with water, are called "hydrophobic", which means "afraid of water".

㊼ O.K., back to chemical bonds in organic molecules. Sometimes atoms are so electronegative (or electropositive) that they do not share electrons at all. But since they either have an excess or shortage of electrons, these atoms are charged or ionized. (This diagram, for instance, shows part of a protein molecule in which a negatively charged group is attracted to a positively charged one.) ㊽ Such an attraction between ionized groups is called an ionic or electrostatic bond. Contrary to what you may have learned in inorganic chemistry, in organic molecules, ionic bonds are about as strong as convalent bonds. Ionic bonds are found in many organic molecules, but they are not nearly as common or important as convalent and hydrogen bonds.

(49) 6. Now our sixth and final point: You may have noticed that certain groupings of atoms occur again and again in organic molecules. (50) The OH group, for instance, is seen in both carbohydrates and nucleic acids. (51) Similarly, the C-double bond-O group and the NH_2 group are quite common. (52) A group of atoms like the NH_2 group has much the same properties wherever it is found. It becomes involved in certain kinds of chemical reactions. It serves a certain function in molecules; such a group is called a "functional group". (53) The NH_2 group is called the amino group. Another functional group is the C-double bond-O or carbonyl group. (54) The OH group is called the hydroxyl group. The COOH group is the carboxyl group. (55) The phosphate or phosphoric acid group is sometimes considered a functional group. (56) The hydrocarbon chain is relatively non-reactive; it is not considered a functional group. There are many other functional groups which needn't concern us here.

(57) Let's briefly look at the functional groups one at a time. First the carbonyl group. The electronegative oxygen of the carbonyl group makes this group extremely polar. Molecules with relatively large numbers of carbonyl groups usually dissolve in water. (58) The carbonyl oxygen often hydrogen bonds with the hydrogen atoms of hydroxyl or amino groups.

(59) The electronegative nitrogen of the amino group hogs electrons, leaving its hydrogens with partial positive charges. Thus, the amino group is polar. Also, the attraction of the nitrogen atom for electrons also explains why the hydrogens of the amino group can hydrogen bond with the negative parts of other molecules.

(60) In fact, the nitrogen atom of the amino group is so electronegative that, under the proper conditions, it can actually attract a positively charged hydrogen atom, or proton, from its surroundings. This gives the amino group a net positive charge; the amino group has become ionized. (61) A molecule or functional group which attracts hydrogen ions is said to be "basic". Such a compound is a base. A base is defined as an H^+ or proton acceptor. The amino group is basic; it accepts protons.

(62) The carboxyl group, on the other hand, is acidic. It donates protons. The double-bonded oxygen attracts electrons so strongly that it even pulls electrons away from the other oxygen. The other oxygen, with its reduced negative charge, can no longer hold onto its hydrogen atom. (63) The carboxyl group donates a hydrogen ion and thus acts as an acid.

(64) The amino acid is a common biological molecule which we can use to illustrate the ionization of amino and carboxyl groups. Under the proper conditions the acidic carboxyl group of the amino acid can donate a proton, while the basic amino group accepts one. The amino acid can have a split personality; it can be at the same time an acid and a base, and it can be positively charged at one end and negatively charged at the other.

(65) Another acidic group important in biological molecules is the phosphate group. It is similar in properties to phosphoric acid. The double-bonded oxygen and phosphorus atoms attract electrons strongly. As in the carboxyl group, the other oxygen is less able to hold onto its hydrogen. (66) The hydrogen ion is easily donated. Thus, the phosphate group acts as an acid. (67) It is the phosphate groups which give nucleic acids, like RNA and DNA, their acidic properties.

(68) The OH or hydroxyl group has varying properties, depending on the situation. The hydroxyl group sometimes ionizes and sometimes acts in a more-or-less non-

polar way. It is found in many kinds or organic molecules, but it is particularly characteristic of sugars and alcohols. The hydroxyl group is often involved in reactions which form a bridge between two molecules. (69) For instance, an OH group on one molecule can react with a carboxyl group in another molecule, forming a bond between the molecules. A molecule of water is formed as a by-product. (70) Since water is formed in this reaction, it is called a condensation reaction. Many reactions which form polymers are condensation reactions. (71) Nucleic acids are held together by condensations between OH groups on sugars and carboxyls on phosphate groups.

(72) The opposite of a condensation reaction is called a hydrolysis reaction. Water is a reactant in the hydrolysis. (73) Hydrolysis results in the breaking up of polymers.

(74) Although many condensation and hydrolysis reactions involve OH groups, other kinds of hydrolysis and condensation reactions are possible, involving other functional groups. For example, the carboxyl and amino groups of amino acids join together in condensation reactions to form protein chains. (75) In your stomach and small intestine, digestive juices hydrolyze your food down to amino acids, which are absorbed into your bloodstream.

(76) Let's briefly review the major concepts discussed in this module:

Organic chemistry is the chemistry of carbon. Most molecules in living organisms are based on carbon backbones.

(77) Many biological molecules are polymers. Each atom in a molecule forms a characteristic number of chemical bonds with other atoms. Most of these bonds are covalent, but hydrogen bonding is also important. Some bonds are ionic. The specific

arrangement of atoms, as well as relative numbers of atoms, are important to the chemical properties of organic molecules.

(78) Polar molecules dissolve in polar solvents; non-polar molecules dissolve in non-polar solvents. Certain functional groups, found repeatedly in many kinds of molecules, display characteristic chemical properties, such as polarity or acidic or basic character. Some of these functional groups react to link molecules together; a common reaction of this type is the condensation reaction.

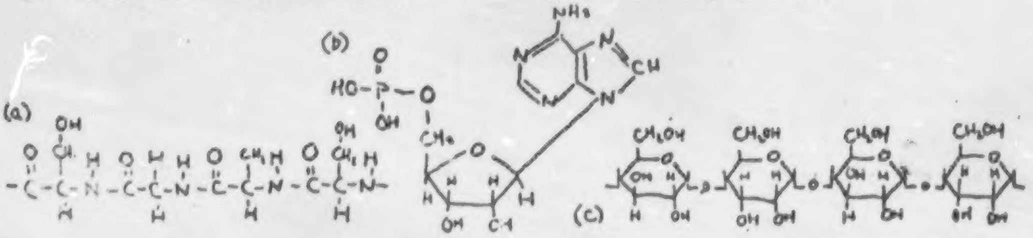
If you want to review any of these concepts in more detail, most biology textbooks contain chapters on chemistry. If you want to delve deeper, you may wish to look in an organic chemistry or biochemistry textbook.

(79) The chemistry of life is complicated and fascinating, but no longer completely mysterious. The concepts outlined in this module should help you to better understand the chemical structure and processes of living things.

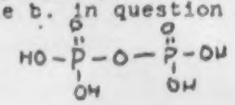
(80)

QUESTIONS

1. Which of these molecules is not a polymer? Explain.


(a)
(b)
(c)
NH₂
CH
HO-P-O
OH
CH₂
CH₂OH

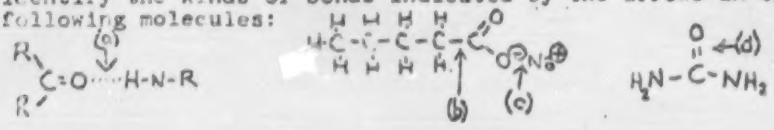
Show how this "pyrophosphate" group might attach to the phosphate group of molecule b. in question #1. (Hint: This is a condensation reaction.)


$HO-\overset{O}{\underset{OH}{P}}-O-\overset{O}{\underset{OH}{P}}-OH$

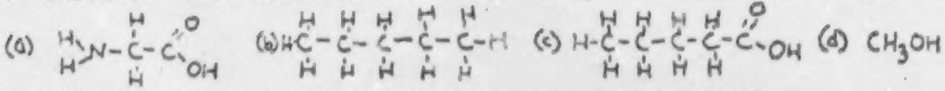
3. If the bond formed in #2 were broken, what would the reaction be called?

4. Name and briefly describe the three main kinds of chemical bonds most often seen in biological molecules.

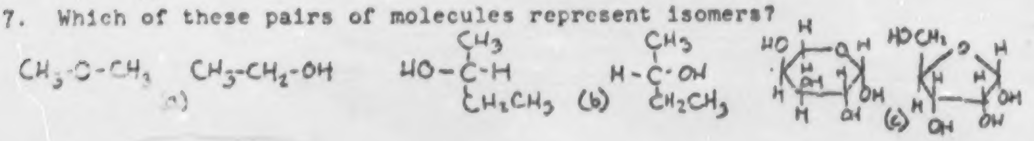
5. Identify the kinds of bonds indicated by the arrows in the following molecules:


(a)
(b)
(c)
(d)
R
R'
C=O····H-N-R
H₂N-C-NH₂

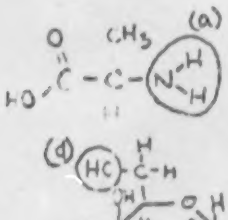
6. Which of these molecules is least likely to dissolve in water? Why?

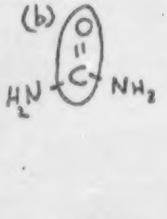


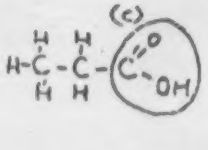
7. Which of these pairs of molecules represent isomers?

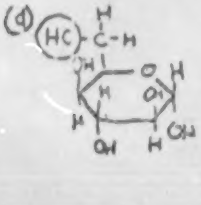

CH₃-O-CH₃
CH₃-CH₂-OH
(a)
HO-C-H
CH₃
CH₂CH₃
(b)
H-C-OH
(c)
HOCH₂

8. Identify the functional groups circled below.









MOD 133 Growing Things
Measuring, interpreting data

OBJECTIVES:

1. Given the necessary materials, you will be able to:
    a. prepare five pots with soil;
    b. plant 30 barley seeds so they will germinate and grow;
    c. care for the growing barley seedlings for a period of 14 days after the seedlings emerge from the soil.
2. After the barley seedlings are about one inch high, you will make daily measurements of the length of at least 15 seedlings.
3. After marking the node where leaves emerge, you will be able to measure the daily growth or elongation rate of the first three leaves produced by each of 15 plants of your choice.
4. You will determine the average daily growth rate of each of the 45 leaves you are measuring.
5. You will attempt to correlate daily weather conditions of sunlight, temperature, etc. with the growth of the leaves.
6. In your experimentation you will devise a method of your choice by which you identify each of the 15 seedlings you are measuring.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, *Life Cycles*, Teacher's Guide
2. ESS, *Growing Seeds*, Teacher's Guide
3. ESS, *Life of Peas and Beans*, Teacher's Guide
4. SAPA 55, *Sprouting Seeds*.
5. Plastic pots, soil, barley seeds, metric ruler, marking pen

FINAL ASSESSMENT:

1. Demonstrate, by showing the instructor the barley plants, that you have been able to grow barley plants for 14 days or more.
2. Present your data to the instructor in a meaningful form.
3. Be ready to discuss the data and defend references you have made regarding them.

PROCEDURE:

1. Obtain from the MOD tray five plastic pots and prepare them for the planting of the barley seeds.

2. After placing the soil into the pots, add desired amounts of water and in each pot place 5 to 8 seeds about ½ inch below the surface of the soil.

3. Cover the pots with Saran Wrap and place them on the flourescent lightstand.

4. Remove the Saran Wrap when the seedlings emerge from the soil.

5. Add water as you feel more water is needed. Refer to the instructional references for proper watering techniques.

6. After the seedlings are about 1 inch high, do the following measurements for the next 14 days.

   a. Find the node on the plant where the leaves begin - a place where the leaf completely encircles the stem. Place a felt-tip pen mark at this location and measure the distance from this point to the top tip of the leaf.

   b. Do this for the other two leaves of the same plant as they emerge.

   c. Measure and record in millimeters the length of the leaves. How can you determine where the elongation takes place?

   d. Record your data for 15 plants in a table form of your own design.

MOD 134 Mitosis
Inferring

OBJECTIVES:

After completing this MOD, you will be able to:

1. name the five stages of cell division in the process called mitosis;
2. name the parts of the cell as shown on the following pages;
3. manipulate two pairs of chromosomes by showing their position in cells during the various stages of mitosis;
4. discuss how the mechanism of division allows each daughter cell to be genetically identical to the parent cell;
5. visualize chromosome structure in a cell and understand the relationship of chromosome structure to the gene concept.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Self Instructional Module 134, The Cell Cycle, Mitosis and Cell Division
2. This MOD, pp. 2-6
3. Denoyer-Geppert Mitosis Models
4. Mitosis wall chart
5. Various biology texts describing the mitotic process
6. Materials on mitosis in the MOD tray

FINAL ASSESSMENT:

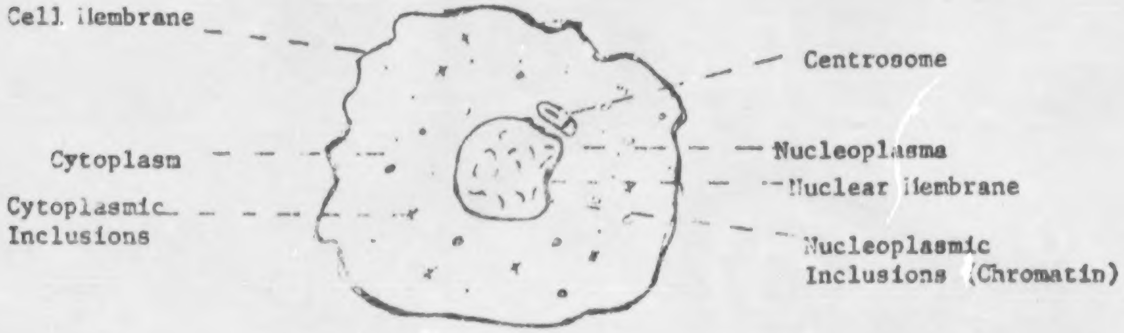
1. See objectives 1, 2, 4, and 5.
2. Demonstrate your achievement of objective 3 by placing the chromosomes in the 8 cell membranes as they appear during the mitotic process.

PROCEDURE:

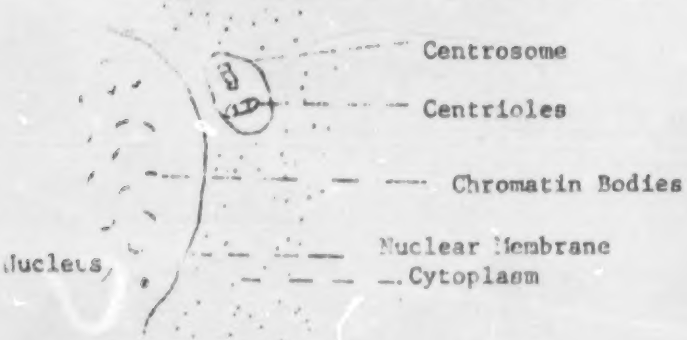
General Information

That cells only come from existing cells is a true statement. With the exception of bacteria and blue-green algae, the process by which new cells are formed from existing cells is called mitosis. It is a very precise process which insures that new cells are identical to parent cells in all important details. More specifically, the mitotic process is primarily concerned with an equal division of the genetic material of a cell so that each new cell will have an accurate and full complement of genetic material or genes. The genetic material (genes) of a cell controls the makeup and function of new cells formed.

Structural Characteristics of Genetic Material
Before understanding how the genetic material is equally distributed in the mitotic process, you should understand the structural characteristics of genetic materials. In every cell there are structural entities called chromatin bodies. Examining a cell under a microscope reveals certain cell parts: cell membrane, nuclear membrane, cytoplasm, nucleoplasm, cytoplasmic inclusions, and nucleoplasmic inclusions. This is a labeled drawing of the parts of a cell.


Cell Membrane
Centrosome
Cytoplasm
Nucleoplasma
Nuclear Membrane
Cytoplasmic Inclusions
Nucleoplasmic Inclusions (Chromatin)

When a cell divides, assume that the cytoplasm and many of the cytoplasmic inclusions are randomly and equally distributed between the two daughter cells. These cytoplasmic constituents may be unequally distributed because the daughter cell can produce most of the cytoplasmic constituents. An exception to this relates to the centrioles. Each cell has two centrioles located in the cytoplasm. The following diagram shows their structure.


Centrosome
Centrioles
Chromatin Bodies
Nuclear Membrane
Nucleus
Cytoplasm

Note that the two centrioles are hollow, elongate rods enclosed in a membrane sac. The entire structure (sac plus centrioles) is called the centrosome and is always on the outside near the nuclear membrane. Because each cell has only two centrioles, it is necessary that they are duplicated before cell division and that two centrioles are placed in each new daughter cell.

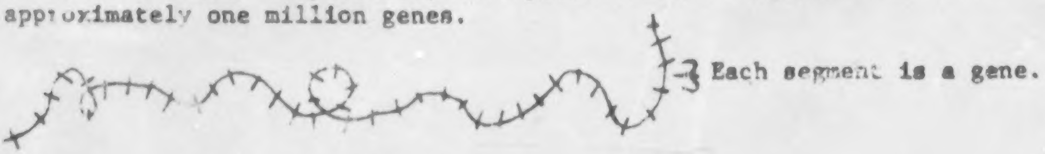
The genetic material (controlling material) of the cell is located in the nucleus. It is important that each daughter cell receive a full complement of these materials. A new cell would die or be impaired if it lacked genetic material, for it could not carry out all the necessary functions of a cell. Therefore, it is very important that the cell has a precise method for duplication and distribution of its genetic material. The genetic materials are the chromatin bodies seen in the nucleus. Their precise method of duplication is the mitotic method.

Nature of Genetic Material

In order to understand the mitotic method it is important to understand the nature of the genetic material. In the diagram, chromatin bodies appear as small granule-like structures. They seem to appear as discrete and independent bodies, but this is not the case. Assume you have a long thin thread so small you can not see it. Although it may be quite long, you can not see it because it is so thin. It does not affect light enough to cause a sensation in the eye. If diagrammed, it would look like this.

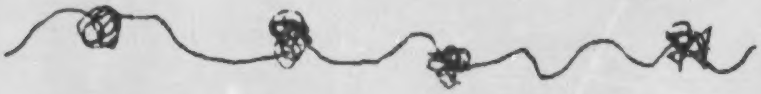
In the drawing, the thin thread-like structure generally appears straight or non-tangled. The thread is composed of chemical substances arranged like beads on a string. The kinds of beads (chemical molecules) used in making the thread-like structure determine the characteristics of any of its parts. A particular part of the thread-like structure, depending on its chemical make-up, has a particular function in the cell. If you relate the structure of any part with a particular function in the cell, then you can call that segment of the thread a gene.

Every organism has a particular set of genes. The human is composed of thousands of cells. Each cell in its nucleus has a full complement of genetic materials. Each human cell has 46 invisible threads. There are two of each kind, or a total of 23 pairs. If you can visualize each of these 23 kinds of threads divided into hundreds of thousands of different segments on the basis of chemical composition, then you understand why the human has approximately one million genes.



Chromatin Bodies or Granules

Understanding the nature of genetic materials is necessary to understand chromatin bodies or granules. These are segments of genetic materials seen in a cell. Even if magnified under the microscope, the thread-like structures are invisible to the naked eye if they are straight. However, assume some parts are not straight and visualize the thread-like structure as illustrated.



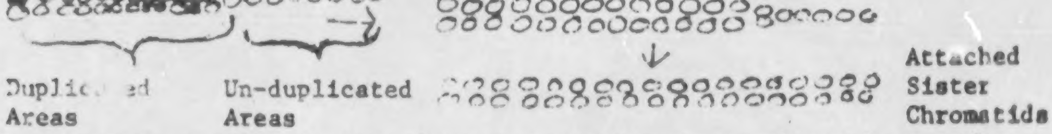
The areas where the thread is clumped (tangled or coiled like a spring) provide enough density or mass in one area so it can be seen if magnified by the microscope. These areas in the nucleus are called chromatin bodies or chromatin granules. Any cell not dividing will show chromatin granules. Remember many of the granules are connected to each other by a fine thread which is too thin to be seen.

Chromatin Thread Duplication

Genetic material of the parent cell is equally divided between two new cells formed in the mitotic process. It is a twofold process. First, before mitosis can give each new cell a full complement of genetic materials, the cell must duplicate all that genetic material. Second, a cell must equally divide all its thread-like structures into equal halves. All the chromatin threads are different, except the paired threads, and each cell must receive one pair of each kind. If these chromatin threads are long, why is it that they do not become tangled and knotted and break when they are separated into two groups?

To understand why they do not break, recall the process of chromatin thread duplication. Visualize these threads as long, thin strands of a bead-like structure as indicated.

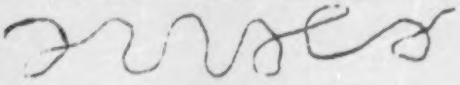
Each bead represents a particular set of chemicals which are in a precise arrangement. Chromosome duplication takes place through lengthwise division, a process possibly beginning at one end. This may be represented as follows.



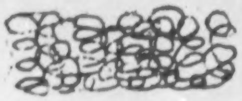
The two strands or threads formed from one original strand remain together as one unit for the initial stages of mitosis. At this stage the chromatin thread consists of two sister chromatids. For example, consider a cell that has 6 chromatin threads. These are paired which means there are only three kinds of chromatin threads (2 of each pair times 3 kinds equals 6). During mitosis, each of the chromatin threads duplicates itself to make a total of 12 threads. Remember that the sister chromatids stick together, although each is a complete chromatin thread. In these 12 threads there are four of each kind and three kinds of chromatin threads (4 of each kind times 3 kinds equals 12).

Chromosomes

If the chromatin threads remained long and thin during the mitotic process, they would be difficult to separate into two equal and identical groups. During the mitotic process chromatin threads change their shape. This is done by a process called coiling. The diagram shows the coiling process.



Before changing shape
long and thin



Coiled
short and thick

The chromatin thread in its coiled form is short, thick, and easily seen under a microscope. The chromatin threads in the process of coiling are called chromosomes. The coiling process is such that a chromosome is formed that has a particular shape and form. Each cell has 2 sets of genetic materials; therefore, each cell will have 2 of each kind of chromosome. It is only during mitosis of a cell that the chromosomes are formed. In a cell that is not dividing its genetic material is in long, thin threads without a specific shape or form.

The Mitotic Process

Both of these aspects in genetic division are essential in the process of mitosis. One, a cell that divides must make an extra set of genetic materials to give each new cell a full complement. Thus, if a cell has a total of 6 chromatin threads, then it has to make 6 more, so that each new cell has 6. Two, the chromatin threads become short, thick, and take a definite shape as chromosomes so that the cell can effectively and equally separate the genetic materials into two halves.

Obtain Self Instructional Module 136, The Cell Cycle, Mitosis and Cell Division. View, listen and study in the A/T carrel.

Useful information to complete these activities:

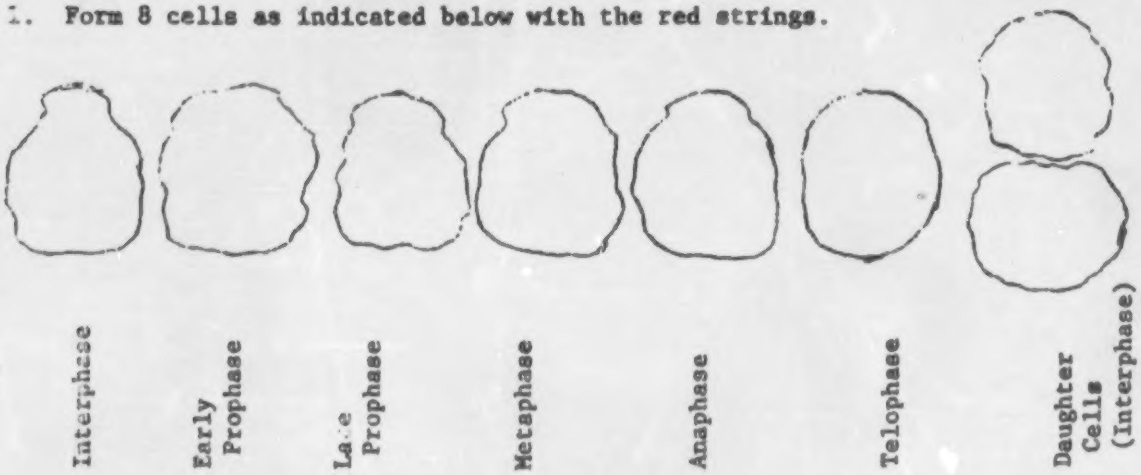
1. Some cells do not have nuclear membranes.
2. Note that some chromosomes are glued together to indicate that the genetic material has been duplicated. The chromatin-chromosomes should be counted as two, even though they are attached to each other.
3. Assume that each cell at interphase has 4 chromatin threads. Each one has an identical twin, meaning that the cell has two pairs.

Activities:

Given the following:

a) 40 chromatin-chromosome pieces (red and black)
b) 8 red strings for cell membranes
c) 4 green strings for nuclear membranes
d) 26 centriole pieces (blue)

1. Form 8 cells as indicated below with the red strings.


Interphase
Early Prophase
Late Prophase
Metaphase
Anaphase
Telophase
Daughter Cells (Interphase)

2. Place the centrioles, chromatin-chromosomes, and nuclear membranes in each cell in both the position and the number in which they appear in the mitotic process.

Self Instructional MOD for MOD 134 The Cell Cycle, Mitosis, and Cell Division

OBJECTIVES:

1. Interpret and correctly use the terms: mitosis, cytokinesis, chromatin, chromosome, chromatid, prophase, metaphase, anaphase, telophase, interphase, S phase, centriole, centromere, spindle, poles, equator, cell plate, cleavage furrow, coenocytic.
2. Name three general phases of the cell life cycle and identify the chief event that occurs in each.
3. Contrast the mechanism of cell division in prokaryotes versus the mechanism in eukaryotes.
4. Compare segregation of hereditary information and cytoplasmic components between daughter cells. Describe the significance of this comparison.
5. Diagram mitosis, showing the processes which occur during each phase; and describe the overall result.
6. Describe the position and/or appearance and the roles of the following at each phase of the cell cycle: chromosomes, chromatids, nucleus, nucleolus, spindle, centrioles.
7. Be able to identify diagrams or photographs of the phases of mitosis.
8. Compare cytokinesis in plants and animals.
9. Describe the result of mitosis without cytokinesis, given an example where it occurs, and name the resulting condition.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on cell cycle, mitosis, and cell division.
3. Biology Media instructional materials
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

INTRODUCTION:

If the cell is the simplest unit of life, it is also the simplest unit that can reproduce itself. The complete study of cellular reproduction demands a plunge into the realm of metabolism. However, with a background in cell structure you can explore the visible, structural events that occur as a cell divides or reproduces. Knowledge of the key events in cell division will be useful when more sophisticated questions are raised about reproduction. The following objectives summarize the essential points you should master.

OUTLINE:

- I. Introduction
- II. Cell Cycle
  - A. Basic processes
    - 1. Synthesis and growth
    - 2. Segregation
    - 3. Cleavage
  - B. Prokaryotic cell cycle
    - 1. Description
    - 2. Time required
  - C. Eukaryotic cell cycle
    - 1. Time required
    - 2. Phases
      - a. G_1
      - b. S
      - c. G
      - d. M^2
    - 3. Relative length of phases
- III. M Phase - mitosis and cytokinesis
  - A. Two main processes
    - 1. Mitosis
    - 2. Cytokinesis
  - B. Mitosis
    - 1. Complex
    - 2. Four phases
      - a. Prophase
      - b. Metaphase
      - c. anaphase
      - d. telophase
    - 3. Prophase
    - 4. Metaphase
    - 5. Anaphase
    - 6. Telophase
- IV. Cell divison-cytokinesis
  - A. Animal cell
  - B. Plant cell
  - C. Mitosis without cytokinesis-coenocytic tissues
- V. Conclusion
- VI. Quiz slides

① The Cell Cycle, Mitosis, and Cell Division

② Living organisms do not form spontaneously. Cells are produced only by the division of previously existing cells. This observation is a fundamental "fact of life." The process which maintains the cellular structure of life is a continual, repeating cycle of cell synthesis, growth, and division called the cell cycle. In this module we will examine the cell cycle in detail.

③ The cell cycle consists of three fundemental processes:

1. Synthesis and growth--This is the production and duplication of the chemicals and structures of the cell.
2. Segregation--the partitioning of cell constituents into two parcels, one for each daughter cell, and
3. Cell division or cleavage--the actual splitting of the mother cell to form two daughter cells.

In general, the first two of these processes take up by far the largest part of the typical cell cycle.

④ In prokaryotes--bacteria and blue-green algae--the cell cycle is relatively simple. A newly-formed cell roughly doubles in size. The genetic material--DNA--is exactly duplicated, exactly doubled. This is the growth and synthesis phase. Then the cell pinches in half in the middle, roughly dividing the cytoplasm and dividing the DNA exactly between the two daughter cells. This accomplishes segregation and cleavage all at once. ⑤ This whole cycle may be repeated as often as every 20 minutes in E. coli, a bacterium commonly studied by biologists.

⑥ In eukaryotes, the cell cycle is much more complex and structured, and it usually takes longer than in prokaryotes.

The processes of synthesis, growth, segregation, and cleavage are seen in eukaryotes, but more specific names are given to the various phases of the cell cycle in eukaryotes.

⑦ The whole cycle takes about 20 hours in a typical eukaryotic cell; that is, 20 hours from the formation of a cell by division until this cell itself divides.

⑧ After the cell is formed, it goes through a period of growth and synthesis, lasting about 8 hours. During this time, the nucleus and cytoplasm enlarge, proteins, carbohydrates and other chemicals are synthesized, and organelles such as mitochondria andplastids reproduce by division. This phase of the cell cycle is called the G_1 phase or first growth phase.

⑨ The G_1 phase is followed by the S phase, during which the cell's genetic information, encoded in molecules of DNA, is exactly reproduced, or "replicated." Each chromosome is duplicated, so that each daughter cell will receive the same information as the mother cell. The S phase lasts about 6 hours.

⑩ After S phase comes the G_2 phase, when the cell apparently makes final preparations for division. The G_2 phase is not well understood. If the G_2 phase is interrupted, the cell will not divide, even though organelles and DNA have doubled. Thus the G_2 phase is necessary for division; but we do not yet know the reason why. The G_2 phase lasts about 5 hours.

⑪ Finally, cellular parts are segretated and the cell divides during the M phase, which lasts about 1 hour in most eukaryotic cells.

⑫ Thus, cell synthesis and growth occur during the G_1, S, and G_2 phases of a typical cell. This period is sometimes called interphase, because it is the period between divisions. Cell components are split up and the cell actually divides during the M phase. ⑬ These are complex processes, so let's focus on the M phase in more detail. The process of segregation of the hereditary material is called mitosis, and division of the mother cell to form two daughter cells is called cytokinesis.

⑭ Mitosis is a complicated process. The survival of both daughter cells depends on them getting exactly the right genetic information. To simplify things, mitosis has been divided into four distinct stages--prophase, metaphase, anaphase, and telophase. ⑮ Prophase begins when the threadlike chromatin, composed of DNA and protein, begins to condense, the dark nucleolus within the nucleus disappears. ⑯ Here are two onion root tip cells in early prophase. ⑰ This is a cell of an early whitefish embryo, called a blastula. It is also in early prophase.

⑱ As the chromosomes appear, they are seen to be double; this corresponds to the duplication of the hereditary material which took place during the S phase. Each chromosome is composed of two identical chromatids, joined at a constriction called the centromere. At prophase, each chromosome consists of 2 chromatids.

⑲ The cells of each organism contain a characteristic number of chromosomes, ranging from 2 to over 400 per cell. In humans the number is 46. Dog cells contain 78 chromosomes, sugar cane cells 80.

⑳ Later in prophase, the nuclear envelope breaks down and disperses. It is thought to move out into the endoplasmic reticulum. ㉑ In this picture of an onion cell the nuclear envelope and nucleolus have disappeared.

㉒ There are two pairs of centrioles in the cells of all eukaryotes except plants. During prophase these pairs move to opposite ends of the cell; these ends are now called the poles. From the poles, the microtubules of the spindle apparatus begin to form. Plant cells lack centrioles, but nevertheless poles and spindle appear in much the same way. ㉓ This slide shows the microtubules developing about the centrioles in a whitefish cell.

㉔ At the end of prophase, the chromosomes move to the equator of the cell, a plane halfway between the poles. ㉕ Here are late prophase in an onion cell... ㉖ and in a whitefish cell.

㉗ At metaphase, the chromosomes are poised at the equator. The nuclear envelope is gone, and the spindle is fully developed. Microtubules of the spindle are attached to each chromosome at its centromere. ㉘ This electron micrograph shows the attachment of the spindle fibers to the centromere. ㉙ This is metaphase in an onion cell...㉚ and this is metaphase in a whitefish cell. ㉛ Finally, this is an electron micrograph of most of a metaphase cell. Note the spindle extending from the lower right to the upper left and the chromsomes lined up at the equator.

㉜ Anaphase begins when the chromatids of each chromosome split apart; each chromosome splits into two chromatids and these chromatids move toward the poles. The microtubules of the spindle have something to do with this movement, but it is not clear whether the microtubules push or pull the chromatids. Some of the microtubules act merely as guides. Incidentally, as soom as the two chromatids of the original double-stranded chromosome split apart, each is called a chromosome. Each is a chromosome composed of a single chromatid, and thus we can say that in anaphase the chromosomes move toward the poles.

㉝ Here is an electron micrograph of two chromosomes moving toward the poles in anaphase. The spindle fibers extend off the picture at the top. The chromosomes move rather slowly, but they do not have very far to go; anaphase takes about 5 to 10 minutes.

㉞ This picture shows anaphase in an onion cell. ㉟ The cell in this picture is at a slightly later stage of anaphase. ㊱ Anaphase in the whitefish cell looks like this.

㊲ With anaphase, accurate segregation of the hereditary information has been accomplished. Usually each chromosome is copied faithfully during S phase, and both daughter cells receive identical information in anaphase.

㊳ In the fourth and final stage of mitosis, telophase, two daughter nuclei begin to form. The chromosomes are at the poles, the spindle disappears, and nuclear envelopes begin to form. ㊴ The chromosomes unwind to form tangled chromatin again, and nucleoli appear in the forming nuclei. Also during telophase, cell division, or cytokinesis, begins. Interestingly, the centrioles reproduce during telophase--the first occurrence necessary for the next mitosis.

㊵ Here is early telophase in an onion cell. ㊶ This is a picture of a whitefish cell early in telophase.

㊷ How long do each of the phases of mitosis last? Metaphase and anaphase occur very rapidly. Prophase takes about 2/3 of the time required for mitosis, or about 40 minutes. Telophase accounts for about 1/3 of mitosis, or about 20 minutes.

㊸ During telophase, the cytoplasm of the cell begins to divide. This process is called cytokinesis. Because of differences in cell structure, there are differences in cytokinesis between plant and animal cells.

㊹ In animals, the cell membrane pinches inward all the way around the cell, almost as if the cell were a ballon which is being squeezed inward to form a sort of groove, called the cleavage furrow. ㊺ Actually, tiny protein filaments inside the cell, called microfilaments, pull the membrane in from the inside to form the furrow. ㊻ The cell membrane pinches in tighter and tighter, until eventually there is just a tiny bridge of cytoplasm connecting the two daughter cells. ㊼ Finally, the two cells are pinched apart.

㊽ During cytokinesis, organelles, molecules, and so on are apportioned randomly between the daughter cells. Each daughter gets whatever is on that side when cytokinesis occurs. Unlike the accurate, structured segregation of genetic information which takes place in mitosis, segregation of cytoplasmic components is random.

㊾ The plant cell is surrounded by a rigid cell wall which cannot just pinch inward like an animal cell. In the plant cell, tiny membranous vesicles which are probably derived from the ER line up at the equator. These vesicles fuse to form the cell plate, which eventually stretches all the way across the cell. ㊿ Finally, the vesicles fuse with each other and the cell membrane, and a cell wall forms in the space, partitioning off the two daughter cells. Again, organelles and molecules in the cytoplasm are divided up randomly. (51) Here is the cell plate forming in our onion root tip cell.

(52) In some organisms and tissues, mitosis occurs without cytokinesis. This may result in a tissue which contains many nuclei (produced by mitosis), but not partitioned by membranes into separate cells. This is called a coenocytic tissue. The coenocytic condition occurs in such organisms as the slime mold, which is essentially one gigantic cell, containing many nuclei. (53) The muscles in our bodies are by-and-large coenocytic. This muscle tissue contains many very long muscle fibers, with dark-stained nuclei lying at intervals along the fibers.

(54) The cell cycle, an endless process of synthesis, growth, segregation, and cleavage, is essential to the perpetuation of life. It began in some primitive cells perhaps three billion years ago, and has continued uninterrupted, generation after generation, to form the cells which make up your body. In your bone

tissues alone, right now, ten million cell divisions are occurring every second. To the cell, and to the organism, cell growth and division are life and death processes. In the game of life, it's double or nothing.

(55) This concludes the tape, but at the end of the module there are several quiz slides which you should try. For each slide, name the phase of the cell cycle, process, or structure indicated, then check your answer by looking at the next slide.

Questions

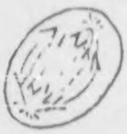
. During which phase(s) of mitosis would you expect to see no nuclear membrane?

2. Briefly describe one difference in mitosis between plant and animal cells.

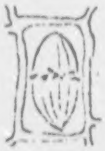
3. Briefly describe one difference in cytokinesis between plant and animal cells.

4. Identify the stages of mitosis represented by the following diagrams:

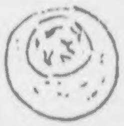
a.



b.



c.



5. What is the difference between "mitosis" and "cell division"

6. During what phase of the cell cycle would you expect DNA polymerase (the enzyme which synthesizes DNA) to be most active?

7. During which stage of mitosis does segregation of genetic information take place?

8. During which stage of mitosis does segregation of chloroplasts take place?

9. What is the major difference between segregation of genetic information and segregation of cytoplasmic components between daughter cells?

10. During prophase, a dividing cell contains 0.2 microgram of DNA. How much DNA is contained in each daughter cell at the end of telophase? How much DNA is contained in each daughter cell after the next S phase?

11. What effect would an inhibitor of microtubule formation have on mitosis?

MOD 135 Cell Division and Growth
Observing, predicting, interpreting data

OBJECTIVES:

1. To learn to identify yeast cells
2. To comprehend that large increases in cell populations occur rapidly
3. To quantitatively follow cell population increases
4. To determine "doubling time" in a population of yeast cells
5. To graphically illustrate the growth curve for a yeast population

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. ESS, Small Things, Teacher's Guide
2. Biology - An Appreciation of Life in Resource Center
3. Dry yeast, microscope slides, cover slips, long pipette, quart jars, tablespoon and ¼ teaspoon measures, unsulfured molasses, unchlorinated water

FINAL ASSESSMENT:

1. See objectives above.
2. For the assessment of objectives 3, 4, and 5, bring your worksheets and graph to the instructor at the time of evaluation.

INSTRUCTIONS:

This MOD consists of several parts which comprise a unit on cell division and cell growth. This is a quantitative MOD designed to determine how much growth has taken place, by counting the number of yeast cells on consecutive days and comparing differences.

ACTIVITIES:

1. About 12 hours before you plan to begin this MOD, make up the following two mixtures on page 122 of "Small Things".
2. Complete the described "Small Things" worksheet, area one, provided in the (MOD) sheets. DO NOT WRITE IN THE TEACHER'S GUIDE.
3. View the filmloop "The Budding of Yeast Cells".
4. Complete the Small Things worksheet, area two provided in the MOD tray. DO NOT WRITE IN THE TEACHER'S GUIDE. Make microscope counts at 0, 6 hours, 24 hours, 48 hours, 72 hours, and 96 hours.
5. Prepare a graph showing the growth curve of your yeast population.

INVESTIGATION 11

Cell Division And Growth

YOUR NAME:

LOOKING AT YEAST CELLS

Make a slide using a small drop of yeast and molasses mixture and a cover slip.

Study your slide and find the yeast cells. Consult the photograph.

1. What does a yeast cell look like?____________________

   ____

2. Draw a picture of several cells.

3. How can you tell the difference between a yeast cell and a small air bubble?____________________

   ____

4. How big is a yeast cell?____________________hw

5. How does a yeast cell compare in size with a paramecium?____________________

   ____

EXAMINING YEAST CELLS THE NEXT DAY

The next day, make another slide of the yeast and molasses mixture and examine it.

1. Do you notice any difference in the size of the cells?____________________

2. If so, are the cells larger or smaller than before?____________________

   ____

3. Is there a difference in the number of cells in a field? ______________________________

4. If you think there is a change in the number of cells, how can you be sure? ______________________________
____

PROBLEMS ON YEAST CELLS

Here are some problems to solve after you have seen the movie *The Budding of Yeast Cells*. You have seen that yeast cells increase in number by dividing. Thus one cell gives rise to two, two cells give rise to four, four to eight, and so on.

1. Complete the table below.

Number of Divisions	Start	1	2	3	4	5	6	7	8	9	10	11	12
Number of Cells	1	2	4	8									

Suppose you have a culture of cells which has just divided. There are now 100 cells.

2. How many cells were there before they divided? ______________

Suppose that you need about 150 cells for an experiment, and that you now have only 10 cells.

3. How many times must the cells divide before you have enough? ______________________________

4. Do you think onion cells and skin cells increase in number as yeast cells do by budding? ______________
Why or why not? ______________________________
____

INVESTIGATION 11

Cell Division And Growth

YOUR NAME:

HOW RAPIDLY DO YEAST CELLS INCREASE IN NUMBER?

To find out how rapidly the number of yeast cells increase in a mixture of yeast and molasses, make a slide with a sample from a fresh mixture.

1. Why is it important to shake or stir the mixture of yeast and molasses before taking a sample? ____________________
____

Examine the slide through the microscope.

2. How many yeast cells did you count in the field? ____________
3. What time was it when you made the count? ____________
4. If your microscope has more than one eyepiece, which one did you use? ____________
5. Which objective lens did you use? ____________
6. Why must you use the same lenses each time that you make a count? ____________

Now move the slide and count another field of cells.

7. How many cells did you count this time? ____________
8. Why is it important to count more than one field of your sample? ____________
9. What is the average of the counts you have made? ____________

Use your answers to the above questions to fill in the first column of the table on Worksheet, Investigation 11, Area Two, page 2.

Your class may decide to work out the answer to the last line (class average) at this time or you may wish to wait until the rest of the table is completed.

10. Why might you want to discover the class average for each count? ______________________________

	Count 1	Count 2	Count 3	Count 4	Count 5	Count 6
Date and time of count						
Time (in hours) since count 1	0	6	24	48	72	96
No. of cells in first field						
No. of cells in second field						
Average number of cells						
Class average						

Six hours after your first count has been completed, make another slide with a sample of the same mixture of yeast and molasses. Examine the slide and count the cells as before. Record the results of count 2 in the table in the spaces provided. The next day make a third count. If you wish, you may also make a fourth count a day later.

11. Look at your table and see if you can figure out how many times the cells have divided:

Between counts 1 and 2 ______________

Between counts 1 and 3 ______________

Between counts 1 and 4 ______________

12. Estimate how long it took for each division to take place. ______________________________

MOD 136 Collecting and Classifying Leaves
Classifying

This MOD is designed to allow you to apply the skill you have developed in classifying in earlier MODs, such as MODs 104 and 106, in a useful way to objects from nature, i.e. leaves.

OBJECTIVES:

At the conclusion of this MOD you will:

1. Present an organized collection of at least 25 leaves from trees (approximately 4.5 meters tall when mature) identified with common names.
2. Present a classification system which you have developed for the leaves.
3. Be able to use descriptions from your classification system to identify a given leaf from your collection or provide a description of a given leaf using your classification system.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SAPA, Commentary for Teachers, in Resource Center
2. Petrides, A Field Guide to Trees and Shrubs, in Resource Center
3. Zim and Martin, Trees, in Resource Center
4. Miller-Jacques, How to Know the Trees, in Resource Center
5. Brockman, Trees of North America, in Resource Center
6. Other books in the main Library on identification of trees
7. Laminator

PROCEDURES:

1. Working with your ISMEP partner collect at least 25 leaves from native trees. Collect enough leaves so that each of you can mount two of each type, one with front exposed and one with back exposed.
2. Using references mentioned above identify the leaf by its common name.
3. Develop a classification system using simple language that will allow you to identify a given leaf within your collection. You may choose to use some of the characteristics used in the keys that have already been developed. You might wish to refer to the SAPA, Commentary for Teachers, "Self-Evaluation" item, p. 66.
4. Mount and organize the collection for presentation and for your permanent file. It is recommended that you mount the leaves on a white background and laminate them.

FINAL ASSESSMENT:

1. Bring collection to the assessment.
2. See objectives.

MOD 137 Growing Crystals
Observing, communicating

OBJECTIVES:

1. Given the chemicals and directions specified on the following pages, you will grow crystals by several different methods, and precisely observe them under the microscope and/or with the naked-eye.
2. Given the observation of growth of crystals in objective 1 above, you will identify the method of formation of crystals in each case, and carefully answer the questions on the following pages.
3. You will find and investigate the crystalline nature of at least two substances in the world around you, and you will bring them to the instructor to be viewed, perhaps under the microscope.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 73, Precipitating Salts from Solution
2. Holden and Singer, Crystals and Crystal Growing
3. Marean and Ledbetter, Physical Science: A Laboratory Approach
4. Thorne Films, Crystals: Growth in Solution, filmloop #568
5. Thorne Films, Crystals: Growth from a Melt, filmloop #569
6. 8 mm. filmloop projector
7. Microscope and chemicals needed for the activities

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

If possible, work in pairs. Some of the materials you will be using are dangerous. Do not permit them to contact your skin and avoid inhaling their fumes.

Discuss the results in the space below each activity. Consider the appearance of the crystals as to shape of face: such as angular, branchlike, tabular, elongated, or blocky. Include the color, the speed of growth, size of crystals, and where the crystals grow.

In answering the questions related to these, it might be well to jot down impressions on separate paper and to write up your final answers only after you have completed all of the activities. You will learn how to discuss the activities by comparing one activity with another activity. This MOD helps you to observe and to describe what you observe.

Activities:

1. View the two filmloops: Crystals: Growth in Solution and Crystals: Growth from a Melt. Read the notes on the filmloop boxes as you view them.

Select either activity 2 or 3.

2. Dissolve ½ tsp. potassium alum in approximately ¼ of a glass of cool water. Continue adding alum by ½ tsp. When no more alum will dissolve, the solution at its present temperature is saturated. Now heat the solution, but do not boil it. When it becomes very hot, add 3 or 4 more tsp. of alum. It should dissolve completely.

Set the solution in a warm place where it will not be disturbed. Set a pencil or straw across the top of the container and suspend a string from the pencil. Tie a small weight, such as a paper clip, on the end of the string so that the string hangs straight into the solution. Do not disturb the container. Let it stand overnight and watch for the beginnings of crystallization the next day. Allow the crystals to grow for several days. What is the shape of the crystals? Describe their growth.

3. Use rock salt and follow the directions given in activity 2. Rock salt is a form of sodium chloride that produces better results for crystal-growing than table salt. What is the shape of the crystals? Describe their growth.

4. You are given a solution of mercuric chloride in nitric acid (2 ml. of HNO_3, 2 ml. of H_2O, and ½ g. of mercuric chloride). Place a drop of this solution on a slide, and view it through the microscope as it evaporates. Wait at least 5 minutes for the growth of the crystals to begin. Where do the crystals first start to grow? Why?

5. You are given a saturated sodium chloride solution. Place a drop of this solution on the slide and watch through the microscope while it evaporates to dryness. Suggest why the crystals of sodium chloride are a different shape from those of mercuric chloride.

6. Weigh out about 15 g. of hypo (sodium thiosulfate) crystals. Put 3 or 4 of the crystals into a test tube with about 2 ml. of distilled water. Add crystals until they no longer dissolve. Heat the test tube gradually, but not to the boiling point, and add crystals continually until all 15 g. are dissolved. The hot solution now holds more hypo than it could hold at room temperature. Gently lower the test tube into cool water to lower its temperature. Carefully lift it out and put in one tiny crystal of hypo as a seed. Accurately observe the results. Feel the test tube and note whether the temperature changes. Did the growth of crystals result in temperature change? Find a reason for this.

7. Melt ¼ tsp. of thymol and place a drop of it on a slide. Place the slide on the microscope platform. When the drop is cool, add a tiny grain of solid thymol. Note the results. Work with liquid and solid thymol to see whether you can contrive situations which give different results in the growth of crystals. Do not throw the thymol away. Keep it in the labeled evaporating dish provided. Why do the thymol crystals have the shape they have? Did you achieve different results by working with liquid and solid thymol? If so, discuss them.

8. Place a large drop of silver nitrate solution (¼ g. $AgNO_3$ in 20 ml. of H_2O) on a slide. As you view it through a microscope, slide one edge of a small piece of copper foil gently into the drop. Observe the crystal growth. Watch especially the initial shape and color of the crystal. Handle the silver nitrate carefully for it stains the surfaces it contacts. Do not throw away the copper foil, but put it in the labeled jar. What are the crystals made of? Why are they located as they are?

List at least three methods of crystal growth you observed in this MOD. Name one or more activity in which each method occurred.

Method — Activity

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Did you notice a relationship between the size of the crystals and the rate of growth? If so, what is it?

Why are crystals of different substances different shapes?

MOD 138 Adding and Subtracting I

This MOD is designed to give a clarity of understanding of the concepts of addition and subtraction.

OBJECTIVES:

At the conclusion of this MOD you will:

1. Have a clear understanding of and skill in addition and subtraction.
2. Be able to present the concepts of addition and subtraction to children in such a way that they will be successful in mastery of skill.
3. Be aware of the fact that attitudes toward mathematics are being formed as addition and subtraction are taught.
4. Describe needed readiness work for children in preparation for addition and subtraction.
5. Analyze a child's errors in addition and subtraction and recognize potential difficulties.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Addition and Subtraction
2. Grades K, 1, and 2 math textbooks in Resource Center
3. Chips, bundling sticks, Cuisenaire rods
4. NCTM 37th Yearbook: Mathematics Learning in Early Childhood
5. MMP slide-tape "Addition and Subtraction in the Elementary School"

PROCEDURE:

1. View the MMP slide-tape "Addition and Subtraction in the Elementary School."
2. Do Activities 1, 2, 3 (make an activity for each of A, B, and C) 4, 5, 6, and 7 (Parts 1, 2, 3, 4, 6) in MMP, Addition and Subtraction.
3. Laminate plans from Activity 3 for your permanent file.

FINAL ASSESSMENT:

1. Bring all work sheets and laminated material to the evaluation.
2. Be prepared to discuss each objective.

MOD 139 Adding and Subtracting II

This MOD is designed to reinforce your understanding of the basic concepts in addition and subtraction.

OBJECTIVES:

At the conclusion of this MOD you will have:

1. Measured your understanding of the concepts of addition and subtraction through a self-test.
2. Reviewed the basic properties of addition and subtraction.
3. Decided on strategies in helping children master the basic combinations in addition and subtraction.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Addition and Subtraction
2. Grades K-6 mathematics textbooks, found in Resource Center

PROCEDURE:

1. In MMP, Addition and Subtraction do Activities 8, 9, 10, 11, 12, 13, and 14.
2. Prepare strategies in a form for your permanent file.
3. Prepare at least one game on addition and subtraction for your permanent file.

FINAL ASSESSMENT:

1. Bring self-test, work sheets, and permanent file materials to the evaluation.
2. Read again and be prepared to answer questions on objectives.

MOD 140 Adding and Subtracting III

This MOD develops the rationale and techniques for the algorithms of subtraction and addition.

OBJECTIVES:

At the completion of this MOD you will have an understanding of:

1. Why the subtraction algorighm causes more difficulty than the addition algorithm.
2. How you can help children to solve addition and subtraction problems.
3. How to use the Papy Mini-computer.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Addition and Subtraction
2. 3 x 5 cards, scissors, tape
3. Grades 3-6 mathematics textbooks, found in Resource Center
4. The Papy Mini-computer with instructions
5. Dienes blocks, bundling sticks, abacus

PROCEDURE:

1. In MMP, Addition and Subtraction, do Activities 16, 17, 20 (put activities on paper), 22, and 26 (summarize strategy of one series).
2. Study the Mini-computer and learn to use it.
3. Laminate the two activities planned for Activity 20 above and the strategy summary.

FINAL ASSESSMENT:

1. Bring all work sheets and laminated material to the evaluation.
2. Demonstrate use of the Mini-computer with your partner.
3. Answer questions relative to objectives.

MOD 141 - Teaching Children: Adding & Subtracting

PREREQUISITE: Consent of Instructor.

OBJECTIVE:

After viewing the video program of "model" teaching your ISMEP-partner and you will plan and teach to four or five children appropriate concepts and skills on adding and subtracting.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Indiana Model Teaching Video Programs on Adding & Subtracting
2. Elementary mathematics textbooks
3. MMP, Addition and Subtraction
4. Video-tape recorder
5. TV monitor

FINAL ASSESSMENT:

Your plan will be discussed with and approved by your instructor(s) prior to the actual teaching experience. Shortly following the actual teaching a 30-minute time period will be scheduled with your instructor(s) to discuss and evaluate the experience. Input from the classroom teacher will be sought and utilized to the extent possible.

MOD 142 Numeration

This MOD is planned to extend your awareness of the role of numeration in the elementary school mathematics program.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Recommend some number readiness activities for primary grades.
2. Relate numbers, number names, and symbols.
3. Diagnose children's problems relative to errors in numeration and suggest remediation.
4. Solve some puzzles using bases.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP Numeration
2. Index cards, paper punch, scissors, knitting needle
3. NCTM 37th Yearbook: Mathematics Learning in Early Childhood

PROCEDURE:

1. In MMP, Numeration do:
   Activities 6; Parts 1, 2, 3, 4, 5, and 6
   9; Parts 1 and 2
   10; Parts 1 and 2
   15; Parts 1 and 3
2. Laminate your activity made from Activity 9; Part 2 for your permanent file.

FINAL ASSESSMENT:

1. Bring your worksheets and laminated activities with you to the evaluation.
2. Be able to answer questions relative to objectives.

MOD 143 Graphing

This MOD is designed to reinforce your graphing skills and to help you apply this concept to the elementary curriculum.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Collect data, choose appropriate type of graph, and construct the graph for data collected.
2. Describe some other coordinate systems.
3. See functions as "input-output" systems.
4. Discuss games and other activities that are standard parts of the elementary curriculum in terms of functions.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Graphs
2. Cuisenaire rods, hinged mirrors, graph paper, balance beam, paper towels, metric ruler, jar, paper clip, Scotch tape, protractor

PROCEDURE:

1. In MMP, Graphs, do
   Activities: 2; Parts 1 and 2 (fill in table)
   5; Parts 1, 2, 3, 4, and 6a
   13; Parts A, 1, 2, and 3; B, 1 and 2; and C, 1 and 2
   14; Experiments 1, 2, 3, 4, and 5
2. Prepare a game for your permanent file, using some concept of this MOD.

FINAL ASSESSMENT:

1. Bring all worksheets and your game to the evaluation.
2. Be able to answer questions relative to objectives.

MOD 144 Rational Numbers IV

This MOD provides the opportunity to review understanding of and skills with integers.

OBJECTIVES:

At the end of these exercises, you will:

1. Be aware of the role of integers in real-world situations.
2. Apply "three resources" to gain insights into problems you will face as a teacher.
3. Have an opinion on "how and when" integers are introduced to the elementary school student.
4. Review and gain new confidence in use of all operations with integers.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. MMP Slide-tape, "Overview of Rational Numbers with Integers and Reals"
3. Paper, scissors, spinners, chips
4. Elementary school mathematics textbook series, found in Resource Center

PROCEDURE:

1. View the slide-tape, "Overview of Rational Numbers with Integers and Reals."
2. Do Activities 1, 2, 3, 4, and 5 in MMP, Rational Numbers.
3. Prepare a game using operations with integers as a part of your permanent file.

FINAL ASSESSMENT:

1. Bring work sheets and your game to the evaluation.
2. Be prepared to answer all questions posed by objectives.
3. Be prepared for brief written test using basic operations on integers.

MOD 145 Rational Numbers V

This MOD analyzes some of the problems children encounter in studying rational numbers.

OBJECTIVES:

At the conclusion of this MOD, you will be able to:

1. Provide examples of common errors children make when working with rational numbers.
2. Give a generalized definition of the operations of addition, subtraction, multiplication, and division.
3. State the properties of rational numbers for the basic operations.
4. Introduce decimals to children.

INSTRUCTIONAL REFERENCES AND MATERIALS

1. MMP, Rational Numbers
2. Elementary school mathematics textbook series, found in Resource Center
3. Dienes blocks in base ten, play money

PROCEDURE:

1. Do Activities 17, 19, 22, 23, and 28 in MMP, Rational Numbers.
2. Prepare an activity designed to deal with some problem children have with rational numbers. Laminate it for your permanent file.

FINAL ASSESSMENT:

1. Bring all work sheets and laminated activity to the evaluation.
2. Be able to respond adequately to each objective.

MOD 146 Rational Numbers VI

This MOD is designed to give you a degree of familiarity with and confidence in using irrational numbers.

OBJECTIVES:

At the completion of this MOD you will be able to:

1. Give examples that would tell us that not all numbers are rational.
2. Give instances where irrational numbers are introduced in the elementary school.
3. Describe the relationships between wholes, rationals, reals, integers, and irrationals.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. Ruler, geoboard, dot paper
3. Elementary school mathematics textbook series, found in Resource Center

PROCEDURE:

1. Do Activities 33, 34, 35, 36, and 37 in MMP, Rational Numbers.
2. Plan an activity to introduce the irrational numbers to an upper elementary class. Laminate this activity for your permanent file.

FINAL ASSESSMENT:

1. Bring all work sheets and your planned activity to the evaluation.
2. Demonstrate ability to fulfill the objectives.

MOD 147 Exploring Children's Thought: Piaget-type Interviews

OBJECTIVE:

1. You should conduct Piaget interviews with at least 6 children, record the results, decide the stage of intellectual development for each of your interviewers based on his responses to the interview tasks (one member of your pair might interview three children while the other member observes and then exchanges roles with the other three interviewers.

2. Given appropriate examples of a child's behavior, you will be able to tell which stage of intellectual development the behavior best exemplifies.

3. You should be able to tell some differences in responses and behavior of two children at different stages of intellectual development.

PREREQUISITE:

View the Piagetian films or videotapes - classification and conservation.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. "Studying the Child's Interpretation of His Environment" from Matthews, C. D., Darrell, G. P., and Good, R. G., Student-Structured Learning in Science. (Duplicated)

2. "Interview Response Sheets"

3. Cassette tape recorder found in Resource Center

SUPPLEMENTARY REFERENCES:

Reprints about Piaget's research and theory in the MOD tray.

PROCEDURE:

1. Arrange to interview at least six children. The youngest should be a pre-schooler.

2. Read the preliminary materials and learn the protocols.

3. Practice on your ISMEP-partner.

4. Conduct the interviews and complete the "Interview Response Sheets" (available in the MOD tray).

5. Record two interviews - one by each ISMEP-partner.

PROCEDURE: (continued)

6. Arrange for discussion and evaluation with the instructor and bring your completed Interview Response Sheets and recorded interviews to the evaluation session.

ASSESSMENT:

You and your partner will schedule a 30-minute time period with the instructor. At that time the completed "Interview Response Sheets" will be reviewed and objectives 2 and 3 will be discussed and the responses evaluated.

MOD 148 Extension of Mathematical Concepts: Numeration, Graphing, Rational Numbers

This MOD is designed to review some concepts in numeration, graphing, and rational numbers.

OBJECTIVES:

At the end of this MOD you will be able to:

1. Design activities to help an elementary school child overcome numeration error patterns.
2. Represent functions by several methods.
3. See functions as special kinds of relations.
4. Recommend possible causes for common errors made by children when working with rational numbers and remedies for these causes.
5. Develop a generalized definition of the operations of addition, subtraction, multiplication, and division.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Numeration
2. MMP, Graphs
3. MMP, Rational Numbers

PROCEDURE:

1. In MMP, Numeration, do Activity 15, parts 1 and 3.
2. In MMP, Graphs, do Activity 13, parts A, B, and C.
3. In MMP, Rational Numbers, do Activities 17 and 19.
4. Make a game for your permanent file to help children with some errors.

FINAL ASSESSMENT:

1. Bring all work and your game to the evaluation.
2. Be prepared to answer questions relative to the objectives.

MOD 149 Flexibility MOD

This MOD-slot is retained to allow flexibility in the program. It is provided to allow the staff to integrate unique occurrences into the program, should they arise.

MOD 150 Communities (SCIS)
Controlling variables, experimenting

OBJECTIVES:

1. You will be able to set up media which will show decomposition and decay of organic matter which is matter composed of dead organisms.
2. You will observe an organism as it decomposes and record your observations.
3. You will be able to discuss the manner in which bacteria and yeast decompose plant and animal materials.
4. You will be able to discuss the functions of water, sand, and air in the decay process.
5. You will be able to discuss the function decomposition plays in the cyclic phenomena seen in all living organisms.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Communities, Teacher's Guide, "Decomposition," pp. 74-83.
2. ESS, Changes
3. Plastic vials with caps, sand, dead animals such as isopods, crickets, mealworms, seeds, plant parts
4. Large glass jar or container, one package of yeast, banana, knife
5. Microscope

FINAL ASSESSMENT:

1. Identify and bring into focus under the microscope a budding yeast cell.
2. Review and discuss the observations you have made in your experiments.

PROCEDURE:

1. After reading SCIS, Communities, "Decomposition," pp. 74-83, set up vials and jars which permit you to observe decomposition by bacteria and yeast.

2. Record data for at least 14 days for the following activities:
   a. Put 2 pieces of banana about the size of a walnut in cups with covers as provided in the MOD tray. Add a small amount of yeast to one cup.
   b. Obtain three kinds of organic matter such as bugs, meat, and leaves. Fill 9 cups with sand. To 3 cups add only organic matter. To 3 cups add water and some organic matter. To 3 cups add only water.
   c. Examine yeast cells or bacteria under the microscope.

3. Using as many of your senses as you dare, on a day by day basis, notice what is happening to the vials. From your observations draw inferences and write logical reasons that support your inferences.

MOD 151 Introduction to Awareness Geometry

OBJECTIVES: After this MOD you will be able (1) to identify, name, and describe geometrical shapes in your environment, (2) name properties and uses of geometric shapes, and (3) analyze shapes to make inferences.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Awareness Geometry
2. Materials:
   a) containers or geometric shapes made by folding and fastening plane shapes
   b) construction paper
   c) rule
   d) scissors
   e) paste
   f) tape

INSTRUCTIONS:

In the MMP, Awareness Geometry read "Introduction to the Awareness Geometry Unit" and answer on paper or make constructions where applicable for:
Activity 1 - Items 2, 4, 5, 6a, b, c, d.
Activity 3 - Items 1, 2, 3, 4.

FINAL ASSESSMENT:

1. Bring papers or constructions to your evaluation session.
2. See objectives.
3. Be prepared to discuss your written records or constructions with the instructor.

MOD 152 Density Determinations

OBJECTIVES:

1. Given the materials in the MOD tray and having completed the activities, you will be able to verbally state and demonstrate by numerical figures the relationship between density and buoyancy in regard to an object floating or sinking.
2. You will be able to determine the density of both an object with an easily determined volume as well as an object with an irregular shape.
3. Given the size and mass of a large inaccessible object, such as a moon or planet, you will be able to determine its density.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. The Everyday Science Sourcebook, pp. 43-44, topics 17-24.
2. Modern Physics; Dull, Metcalfe, Williams; pp. 191-192, topics 21 and 22. Read the sample problems and solutions on pp. 193 and 194.
3. Wooden blocks, rocks and other objects in the MOD tray, a balance scale

PROCEDURES:

1. In the MOD tray you will find two blocks of wood, of obviously different sizes and weights. Measure the volume of each one in cubic centimeters, and weigh it in grams. Determine the densities in g/cm^3.

   ____________________   ____________________

2. There are also three objects of such shapes that one cannot measure them directly. Find the volumes of each of these by use of an overflow tank. (Refer to MOD on Float or Sink.) Then weigh the objects and determine their densities.

DISCUSSION:

Most planets are in the general size range of the earth, and have comparable masses. Astronomers can determine these masses even though we have not actually been to the other planets yet. The size is determined on the basis of linear diameter. As all of them are spherical in shape, one can obtain the volume from the diameter. Consult a math book in the Resource Center to find the formula for the volume of a sphere.

3. Given the diameter of Mars to be about 4200 miles, or about 6800 km, and the mass to be about 6.45×10^{23} kg, or 644800000000000000000000 kg, find the density of Mars in g/cm^3.

4. Our moon has a diameter of 2160 miles or about 3540 km, and a mass of about 7.34×10^{22} kg or 73400000000000000000000 kg. Find the density of the moon in g/cm^3.

FINAL ASSESSMENT:

Bring all your records and problem solutions to the evaluation session and be prepared to answer questions relevant to the objectives as stated previously.

MOD 153 Nutrition
Interpreting Data, Formulating Hypothesis

OBJECTIVES:

1. After completing the exercises, you will be able to describe tests for starch and sugar.
2. After completing the exercises, you will be able to identify at least two variables that will inhibit the function of an enzyme.
3. You will be able to describe the function of saliva in digestion.
4. You will determine one or more variables other than those used in this experiment that inhibit the digestive function of saliva; then test for the effect of these variables.
5. Test several items for the presence of starch.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. The pages of this MOD
2. Units on digestion in general biology references

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

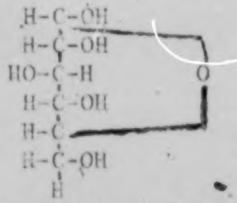
Digestion as a part of nutrition

The terms digestion and nutrition are often confused. Nutrition involves the supplying of all substances needed to promote growth, maintenance, repair and reproduction of living organisms. Included in nutritional needs are the fuels (carbohydrates, proteins, and fats), water, vitamins, minerals, and the gases (O_2 and CO_2) either needed or produced by the organism. Not all organisms have the same nutritional requirements.

Digestion is the process which converts the fuels into their smaller component units that are in turn utilized by the organism in metabolic respiration which supplies the energy (ATP) used by the individual cells of an organism.

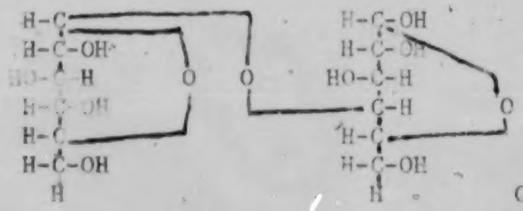
The process of digestion concerns the manner in which food stuffs are prepared to be taken into cells where they are used. Digestion most often occurs outside the body of animal organisms; food that one has eaten is placed in the digestive tract (mouth, stomach, intestines) and, in a sense, is still outside the body. This is true because the intestinal tract is a hollow tube running through the body that is open at both ends. Food material can be considered to be in the body once it has been absorbed through the walls of the intestine. Digestion concerns the processing of food stuff so that it can effectively be absorbed through the walls of the intestine, into the blood stream, and into cells of the body. Most digestion occurs in the small intestine.

This exercise concerns the digestion of one of three main kinds of organic food stuffs--(fuels) carbohydrates. The other two principal kinds are fats and proteins. Starch, a carbohydrate, is composed of only one kind of building block called glucose. The molecular structure of glucose is sketched below. It contains 6 carbon atoms bonded or hooked together into a chain. Each carbon atom has attached to it some hydrogen and some oxygen. A glucose molecule has a total of 12 hydrogen atoms and 6 oxygen atoms.



Glucose

The glucose building blocks can be hooked together in groups of two as shown below to form the sugar, maltose.



Glucose + Glucose = Maltose

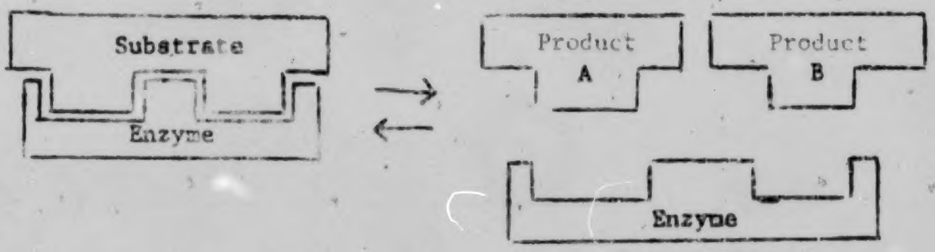
This combination is composed of two glucose molecules bonded together and is called maltose. Starch is composed of many glucose units bonded together to form long chains. This can be shown by a formula in which "n" stands for many glucose molecules.

$$\text{Glucose-(Glucose)}_n\text{-Glucose}$$

Most foods contain starch. The starch molecule, composed of many glucose units bonded together, can not be absorbed through the cellular walls of the digestive tract. The molecule is too large to pass through the pores in the cells that line the intestine. The starch molecule must be broken down into units of 2 glucose molecules (maltose). From the maltose form, it is further broken down into individual glucose units. Glucose molecules pass through the cell membranes and are absorbed from the digestive tract. How does the body in the process of digestion break up the starch molecules into maltose and then into glucose units?

Most chemical reactions in a living organism are controlled by substances called enzymes. Enzymes are chemical substances usually made of protein that attach themselves to other chemical molecules and cause them to break up into smaller units. We can also think of enzymes as chemical substances to which two smaller molecules become attached. The enzyme then causes the two smaller substances to react with each other and to become bonded together. In this way, enzymes serve either to break large molecules into smaller ones or to make larger ones from two or more smaller ones.

The enzyme and the other substances on which it works must somehow fit together like the pieces of a picture puzzle. The following diagrams illustrate this principle called the lock and key mechanisms of enzyme function. The substance that an enzyme works on is called the substrate.



Note that the enzyme remains unchanged. Also note that the reaction could proceed in either direction. That is, it could break the substrate into two smaller ones or make a larger molecule from two smaller substrates.

To understand enzyme function three concepts are important to remember.

1. Because of the lock and key mechanism of enzyme function, each kind of organic reaction must have its own enzyme.

2. An enzyme molecule has 2 distinct parts; one is protein and the second is non-protein (many vatamins serve in this latter capacity). Anything such as heat, pH (acid and/or base), light, cold, or salts that affects the protein part of the enzyme molecule and changes its shape will be effective in preventing the enzyme from functioning.

3. All organic or inorganic molecules have a characteristic shape and form under a given set of conditions. Shape and form means that the external configuration is distinct for that kind of molecule.

   In this experiment you work with one kind of substrate which is starch. You work also with one kind of enzyme called amylase. Amylase, produced by the salivary glands, is one of the substances found in saliva. Amylase as an enzyme attaches itself to the starch molecule and breaks it into maltose. Remember that maltose is a molecule composed of two glucose units bonded together.

   You need to know and to use the following simple tests in doing nutrition (digestion) experiments.

   Simple Tests:

   1) When I_2KI (Iodine) is added to starch, a deep blue-black color results.
   2) When Benedict's solution is added to starch and boiled for about one minute, it remains a light blue color.
   3) When I_2KI is added to glucose or maltose the result is a brownish (iodine) color.
   4) When Benedict's solution is added to glucose or maltose and boiled for about one minute the color changes to a yellow-orange or brick red color depending on the amount of sugar present.

Activities:

1. Heat a 400 ml beaker ½ full of water to boiling on a hot plate.

2. While the water is heating, obtain a clean test tube from the MOD tray and add about 10 ml of saliva to the tube. This is done by collecting saliva in your mouth and puttin it in the test tube. Thinking about food or chewing a clean rubber band may help you salivate. If you have eaten, drunk, or chewed gum recently, you should rinse your mouth thoroughly with water before collecting saliva. Divide the 10 ml of saliva equally into two test tubes. Stand one of these tubes of saliva in the boiling water for 10 minutes, then allow to cool before using. Label the proper tubes "non-boiled saliva" and "boiled saliva" with the labels in the MOD tray.

3. Obtain 13 clean test tubes from the MOD tray. (Clean them if necessary before using.) Number the tubes from 1 to 13 with a wax pencil. To the proper tube add the subtances listed below; mix substances by shaking the tube gently or by rolling the tube between your hands.

   Allow all tubes to set 10 minutes before performing any other tests as directed in paragraph #4.

Tube #1	10 drops starch solution
Tube #2	10 drops starch solution 10 drops iodine solution
Tube #3	10 drops starch solution 10 drops Benedict's solution
Tube #4	10 drops non-boiled saliva 10 drops starch solution
Tube #5	10 drops non-boiled saliva 10 drops starch solution
Tube #6	10 drops boiled saliva 10 drops starch solution
Tube #7	10 drops boiled saliva 10 drops starch solution
Tube #8	10 drops starch solution 10 drops HCl 10 drops non-boiled saliva
Tube #9	10 drops starch solution 10 drops HCl 10 drops non-boiled saliva
Tube #10	10 drops starch solution 10 drops NaOH or KOH 10 drops non-boiled saliva
Tube #11	10 drops starch solution 10 drops NaOH or KOH 10 drops non-boiled saliva
Tube #12	10 drops maltose
Tube #13	10 drops maltose

4. After test tubes prepared in #3 above have set for ten minutes, proceed as directed below:

To test tube #4: add 10 drops iodine solution and mix
#5: add 10 drops Benedict's solution and mix
#6: add 10 drops iodine solution and mix
#7: add 10 drops Benedict's solution and mix
#8: add 10 drops iodine solution and mix
#9: add 10 drops Benedict's solution and mix
#10: add 10 drops iodine solution and mix
#11: add 10 drops Benedict's solution and mix
#12: add 10 drops iodine solution and mix
#13: add 10 drops Benedict's solution and mix

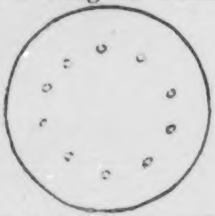
5. Before proceeding further, observe all tubes for any apparent reactions such as color changes. Record your observations.

6. You are now ready to place all the tubes in boiling water for approximately five (5) minutes. At the end of five (5) minutes examine each tube and record its appearance. (Look for such things as color (changes), cloudiness, and precipitation.)

7. Explain what has happened in each tube (or explain why nothing happened).

8. A method to show the speed of digestion (or that digestion is occurring) is as follows:

   a) In a clean petri dish half, place a ring or series of iodine solution drops.



   b) In a clean test tube place 10 ml of starch solution and add one ml enzyme solution, mix by swirling the test tube. Immediately after mixing (and have a partner note the time) use a pipette to remove a small drop of the mixture. This drop is placed in one of the previously prepared test drops of iodine. At the end of one, two, three, four, five minutes, etc. remove another drop and place in an unused iodine drop to observe results. NOTE: wash the pipette thoroughly between each sampling.

   One should see a gradual decrease in iodine-starch test color until finally no color change is noted.

   Ask yourself, "What has happened to the starch?" Was it digested to sugar? What test can you use to determine whether this last mentioned event occurred?

9. Test one or more other items for the presence of starch.

MOD 154 Geometry in Structures

OBJECTIVES: After this MOD you should be able to (1) analyze two geometric forms and predict which is more stable (2) build a tower and a bridge utilizing stability principles and (3) calculate the mass ratio between the materials used in construction and the load supported by a bridge.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Awareness Geometry
2. ESS, Structures
3. Materials:
    - Paper strips (3 cm x 20 cm)
    - Paper hole punch
    - Brass brads
    - Scissors
    - Plastic soda straws
    - Paper clips
    - Metal washers
    - Thread

INSTRUCTIONS:

1. From the MMP, Awareness Geometry, complete Activity 2, Items 1, 2, 3, 4, and 5, writing answers or performing constructions or activities as outlined.
2. From the ESS, Structures read the "Introduction" and perform activities suggested by the questions in "Straws and Pins," pp. 20-27.
3. Compare the ratios of mass of materials for at least two different bridges from "Straws and Pins" and draw a sketch of the one with the larger ratio.

FINAL ASSESSMENT:

1. Bring written exercises to the evaluation.
2. Bring constructions where appropriate. If not appropriate, sketch the construction.
3. See objectives.

MOD 155 Brine Shrimp
Controlling variables, experimenting

OBJECTIVES:

1. You will be able to design an experiment which will show the relationship between the salt concentration in the water and the hatching reliability of brine shrimp eggs.
2. You will design an experiment to determine the effects of overpopulation in salt water.
3. You will design an experiment to determine the effects of chemical pollutants (i.e. soapy water, alcohol, vinegar, etc.) on brine shrimp.
4. You will be able to graph the results of your experiment in a meaningful way.
5. You will be able to accurately record your experimental data.
6. From your daily observations of brine shrimp eggs, you will be able to determine: 1. What amount of the salt per unit volume of water is best for the hatching of brine shrimp eggs; 2. What is the optimum number of brine shrimp per unit volume of water; 3. What are the effects of various chemicals on brine shrimp development.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Environments, Teacher's Guide, "Brine Shrimp in Salt Water"
2. ESS, Teacher's Guide for Brine Shrimp
3. Rock salt (sodium chloride), culture dishes, medicine droppers, teaspoons, hand lens, brine shrimp eggs

FINAL ASSESSMENT:

1. Present to the instructor:
    a. your experimental design;
    b. your data;
    c. your graphs;
    d. your conclusions about the experiment.
2. Be ready to defend critically your conclusions based upon experimental evidence.

PROCEDURE:

After reading and studying ESS, Brine Shrimp, and SCIS, Environments, "Brine Shrimp in Salt Water," pp. 66-67, set up an experiment to determine the optimum amount of salt needed for brine shrimp eggs to hatch. Do not use teaspoonsful of salt as suggested; rather vary salt concentration between 2% and 5%. Use the experimental procedure suggestions from SCIS, Environments if you wish. After formulating a written plan of experimentation, present your design to the instructor before doing the experiment.

Note these suggestions and precautions.

1. Brine shrimp eggs are very small; moisten a paperclip, and lightly touch it to the supply of dry eggs.
2. Water in open dishes evaporates. Maintain the water level by adding distilled water at room temperature. Does salt evaporate?

MOD 156 **Pendulums**
Communicating, inferring

OBJECTIVES:

1. Given the materials in the MOD tray, you will construct a "one-second pendulum" to be used as a timer for the activities in this MOD.
2. Using the pendulum support and the materials in the MOD tray, you will become familiar with the behavior of pendulums in general. For example, vary the size, weight, or shape of the bob, the length of the pendulum, etc.
3. Using a simple ball pendulum, you will observe, record, and graph the variation of the period of the pendulum as its length is changed.
4. Using several objects from the MOD tray as pendulum bobs, you will measure and record their lengths when they are adjusted to a period of one second.
5. After viewing the filmloop Sand Pendulum I, and after referring to the Teacher's Guide for Pendulums, you will construct a sand pendulum and study its behavior as you use it to make various sand patterns.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Pendulums, Teacher's Guide
2. Filmloop, Sand Pendulum I by ESS
3. Physical science texts
4. Pendulum bobs, strings, supports, tongue depressors, razor blades meter sticks, timer, conical paper cups, sand

FINAL ASSESSMENT:

1. Demonstrate your timer and sand pendulum for your instructor.
2. Bring to your instructor the data and graphs resulting from the activities in the MOD, and be ready to discuss your answers to the questions on pp. 2-3.

PROCEDURE:

1. To make a simple timer, suspend a bob from a support with the bob swinging freely. Refer to ESS, Pendulums, p. 49. Adjust the length of the string until one complete swing, to and fro, takes one second. It is better to time 20 to 40 swings than to time one swing. The time to go to and fro is called the period of a pendulum. You now have a timer for other activities in this MOD.

2. Using a simple ball pendulum, measure and record the period of this pendulum for different string lengths.

Trial	Length	Period
1	10 cm	________ sec
2	20 cm	________ sec
3	30 cm	________ sec
4	40 cm	________ sec
5	50 cm	________ sec

Formulate a statement about the relation between the length of the pendulum and its period.

Show this relation between the length and period of a pendulum by graphing your results.

3. Using several objects from the MOD tray as pendulum bobs, prepare a one-second pendulum with each and measure the length of the string. Time 20 to 40 swings and take an average.

Object	Period	Length of String	Weight
Steel Ball	1 sec	____________	________
Glass Ball	1 sec	____________	________
2-in Wooden Ball	1 sec	____________	________
4-in Wooden Dowel	1 sec	____________	________
Washer	1 sec	____________	________

In the space below, describe and compare the behavior of these pendulums.

4. View the filmloop, Sand Pendulum I. Refer to the filmloop and to ESS, Pendulums, p. 45, and then construct your own sand pendulum. Experiment with it to obtain various sand figures on the table. Use paper under the pendulum to catch the sand. Be ready to demonstrate your sand pendulum for your instructor.

. Using the large wooden ball from the MOD tray, prepare a pendulum suspended from the ceiling. Start with the bob 8 cm. from the floor. Measure the period (a). Then shorten the length 30 cm. at a time and measure the period each time (b-f).

	Distance from floor	Period
a.	8 cm	sec
b.	38 cm	sec
c.		sec
d.		sec
e.		sec
f.		sec

MOD 157 Teaching Geometry to Elementary Children (an individual MOD)

PREREQUISITES: MODs 151 and 153

OBJECTIVES:

During this MOD you will demonstrate the ability to choose a geometry lesson from an elementary mathematics text, determine appropriate objectives for the lesson, and plan a procedure for utilizing what you learned in MODs 151 and 153 in teaching the lesson to elementary children.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Awareness Geometry
2. John Egsgard, "Geometry All Around Us - K-12", The Arithmetic Teacher, (October 1969), pp. 437-445. (Copy found in MOD tray)
3. Environmental Geometry, (Nuffield Mathematics Project), New York: John Wiley & Sons, Inc., 1969. (Found in Resource Center)
4. One or two elementary mathematics textbooks.

INSTRUCTIONS:

In the MMP, Awareness Geometry, do Activity 6, Items 1, write Item 2a, b, c, (prepare c for your file), 4, and 5. Discuss with an instructor prior to the scheduling of Item 3. Item 3 will be a scheduled group activity in an area school.

FINAL ASSESSMENT:

Successful completion of this MOD will be determined by an instructor's acceptance of satisfactory completion of the activities including Item 3.

MOD 158 Spinning Tables
Experimenting

OBJECTIVES:

1. Given the items listed below and the information in the MOD, you will design and carry out an activity in such a way that the important variables have been controlled well enough so that concluding remarks are valid.
2. Given the items listed below, you will be able to write a science exercise for fourth graders using the materials and ideas from ESS, Spinning Tables and correlate it to materials found in the Heath textbook, Schneider, Science in Your Life (4), "Force and Moving Things," pp. 207-222. This exercise will be written in a process oriented inquiry style. You will see if you can adapt an inquiry style lesson to a traditional content oriented science textbook.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Spinning Tables, Teacher's Guide } to be obtained from lab asst.
2. Class kit of materials for "Spinning Tables" }
3. Schneider, Herman and Nina, Science in Your Life (4), pp. 219-254, in Resource Center

FINAL ASSESSMENT:

1. Bring to your instructor all data sheets for objective 1 and be prepared to defend your conclusions. The instructor will try to find weaknesses in your conclusions.
2. Bring to your instructor the exercise you have written to complete objective 2.

PROCEDURE:

Read the entire ESS, Spinning Tables, Teacher's Guide to learn how the material is used in the classroom. Then proceed with objective 1 as an elementary student in the ESS program might do.

1. "Mess around" with the materials in any way you like and for as long as you like. This enables you to see how the spinning table works and to see the behavior of some objects on it.

2. Design and carry out an activity of your choice using the following format.

A. State in question form the problem you would like to solve. For example: What is the relationship between the weight of a marble and the time it takes for it to fall off the spinning pegboard?

B. State a hypothesis based on intuition from previous experience. For example: The heavier the ball the sooner it falls off the pegboard.

C. State possible variables that might be related to the problem. For example: Diameter of the sphere, where it is placed on the table, speed of wheel, etc.

D. State how you would control all the variables except the variable in your hypothesis. For example: To control the diameter variable of the marble, use two marbles of the same size but of different weights.

E. Carry out the experiment for several trials by controlling the variables mentioned in D and record your results.

Trial #1

Trial #2

Trial #3

Trial #4

Trial #5

etc.

F. Accept or reject your hypothesis and state a conclusion based on your data.

3. Read Chapter 7, "Force and Moving Things," in the 4th grade science book by Herman and Nina Schneider, Science in Your Life, pp. 219-254. Create an inquiry method exercise for 4th graders on the concept of force and motion using the materials of ESS, Spinning Tables. Follow the format of the Schneider text under "Experiment" and "Problems." Refer to pp. 222-223. If you read the experiment on p. 222 and the topic, "Resistance and Friction," p. 223, you might notice that a perceptive student could find the answers by careful reading.

In designing your lesson try to avoid writing an experiment with just one possible "answer" and also try to avoid questions to which answers are obvious.

MOD 159 Organisms
Observing, classifying, inferring

OBJECTIVES:

After preparing a hay-infusion aquarium and observing it for two weeks, you will be able to:

1. set up an aquarium using hay-infusion materials;
2. describe day-by-day changes in the physical appearance of the aquarium over the two week period;
3. describe the sequence in which different organisms appear in the aquarium during the two week period;
4. set up a classification scheme for the organisms you saw in your aquarium;
5. make inferences about why population numbers increased or decreased at different times during the two week period;
6. apply the following concepts to everyday situations other than the examples in this MOD:
    - a) organism
    - b) death
    - c) food chain
    - d) birth
    - e) habitat
    - f) detritus
    - g) herbivore
    - h) food web
    - i) carnivore
    - j) omnivore
    - k) predator
    - l) prey
    - m) parasite
    - n) host
    - o) producer
    - p) consumer
    - q) decomposer
    - r) scavenger

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Organisms, Teacher's Guide
2. ESS, Pond Water, Teacher's Guide
3. SAPA, 94, Small Water Animals
4. ESS, Small Things, Teacher's Guide
5. General biology texts, the sections about food chains and food webs
6. Gallon jar, distilled water, materials for making hay-infusion, compound microscope, stereoscopic microscope and/or hand lends, slides, cover slips, and pipette
7. Smith, Robert L., Ecology and Field Biology, 2nd edition, Harper and Row, pp. 42-62, especially pp. 42-54.

FINAL ASSESSMENT:

During your oral evaluation with the instructor:

1. Present descriptions of the organisms, sketches of the organisms, and the identification of those organisms according to the classification system which you used.
2. Discuss and support plausible reasons for (a) the sequential appearance of organisms in the aquarium; (b) the resulting environmental change; (c) the increase in organisms to a certain point and their resulting decrease or point of stability.
3. See objective 6.

PROCEDURE:

The hay-infusion material which you use was collected last August or September. It was prepared as follows:
a. We collected one pint of soil-organic debris from the bottom of a stream or lake.
b. We collected an assortment of plants and leaves growing near the edge of the water or in the water.
c. We placed the above items in a gallon jar filled with lake or stream water.
d. We placed the jar and its contents in a warm place to allow the water to evaporate.
e. After the materials were semi-dry, we placed the contents in a pan and stored them in a dry place.

A variety of organisms present in hay-infusion material will grow and flourish when water is added.

1. Prepare your aquarium by adding two quarts of spring water to 15 grams of hay-infusion material in a one-gallon jar.

2. Label the aquarium with your name.

3. The aquarium should be set on the window ledge of the south side of the room.

4. Make daily observations of your aquarium for at least 14 days.

5. Find at least seven organisms in your aquarium and classify them according to your own system. Be sure to record:
   a. an observation and description of the organism;
   b. a sketch of the organism in which you specify magnification;
   c. the identification of the organism.

   Record and sketch your daily observations. Quantitatively determine the numbers of different kinds of organisms in the jar each day. Record the sequential development of the organisms. Each day stir the contents of the hay-infusion jar before making your observations. Remove a medicine dropper full of the mixture, place it in a small dish, and look for the organisms by using a stereoscopic microscope. For better identification, place a drop or two of the mixture on a glass slide, cover with a cover slip, and examine the organisms under the compound microscope. Take careful note of any environmental or population changes. Prepare a graph to show each organism's increase to a certain point and then decrease, stabilization, or disappearance. Hypothesize possible interactions between the organisms and environment to account for this.

MOD 160 Introduction to Standard and Non-standard Measurement Units

" . . . Measurement involves an attribute, a unit, the comparison of a quantity of the attribute with the unit, and the assignment of a number to the quantity of the attribute." MMP, Measurement. This MOD is designed to provide experience with each of these processes.

OBJECTIVES:

At the conclusion of this MOD you should be able to:

1. Name some attributes and tell how they might be measured quantitatively.
2. Illustrate some non-standard units of measure and describe some advantages and disadvantages of the units.
3. Name the common units of linear measurement in the English system and state the relationship among them.
4. Name the common units of linear measurement in the metric system and state the relationship among them.
5. Change a measurement from one English unit to another or from one metric unit to another.
6. Describe some major advantages of the metric system for making linear measurements and calculations.
7. Make reasonable linear estimates in metric units.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Measurement
2. Meter sticks
3. Balance scales
4. Liter containers
5. Coffee cup
6. Drinking glass
7. Door key
8. Filmstrips/Tapes: History of the Metric System and Advantages of the Metric System.

INSTRUCTIONS:

In the MMP, Measurement, read the introductory material, pp. 5-16. Answer the questions or perform the exercises for: Activity 1; items 2, 3, and 4. Activity 2; items 1, 2, 3, and 4. Activity 3; items 1, 2, 3, 4, and 5. Listen to the tape and view the filmstrip for each of History of the Metric System and Advantages of the Metric System.

FINAL ASSESSMENT:

1. Bring all papers to the evaluation.
2. See objectives.
3. Be prepared to discuss your records and the filmstrips with the instructor.

MOD 161 Defining Operationally (Group Activity)(SAPA)
Analysis of mixtures

DEFINING OPERATIONALLY

"Scientists state operational definitions in terms of 'what you do or what operation you perform' and 'what you observe'....In [this SAPA sequence, students] will be expected to define terms in the context of their own experiences. They [may] not use an operational definition that would be entirely acceptable to scientists, but they should always use the criteria applied by scientists in constructing their definitions. That is, they should strive to state precisely what to do and what to observe in order to identify the term being defined." SAPA, Supplement to the Guide for Inservice Instruction, p. 9.

OBJECTIVES:

1. Given 5 powders, 3 test solutions, and some materials for conducting a heat test, you will find out all you can about each of the powders through observing them and their reactions in any test you can invent. Record your findings on the blackboard and in the spaces provided on the following pages.
2. Having investigated the 5 powders, you will define each of them operationally and classify them according to these definitions.
3. Given samples of 3 unknown powders containing combinations of 2 or more of the 5 mystery powders, you will use knowledge gained in objective 1 to identify the components of the unknowns.
4. Select at least 3 objects from your everyday world and formulate operational definitions that would enable a person unfamiliar with the objects to identify them from your definitions.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 67 , Identifying Materials
2. SAPA, 81 , Analysis of Mixtures
3. ESS, Mystery Powders
4. 5 powders
5. 3 test solutions
6. Wax paper, souffle cups, toothpicks, candles, aluminum foil

FINAL ASSESSMENT:

1. Present your operational definitions and your classification scheme to your instructor. See objective 2.
2. Present your analysis of the unknowns and be ready to defend your decisions about which powders are present. See objective 3.
3. See objective 4.

PROCEDURE:

Given: Powders 1, 2, 3, 4, 5
Test solutions A, B, C
Candles and aluminum foil for heat test
Unknowns X, Y, Z

Find out all you can about the powders by observing them and their reactions to heat and to the test solutions. Remember, observing may involve any or all of the five senses. As you construct your own data sheets share your knowledge by contributing to the large data sheet sketched on the blackboard.

DATA SHEET: Discrepancies should be resolved before proceeding to pp. 3-4 of this MOD.

Defining operationally: Classifying

An operational definition is one stated in terms of operations performed, or "what you do," and the perceived results of those operations, or "what you observe." The following example is an operational definition of carbon dioxide. Carbon dioxide is a colorless gas that will suffocate fire and that will turn limewater milky when it is blown into the limewater.

In the space below, formulate operational definitions for each of the 5 powders. On the reverse side of this sheet construct a classification key which differentiates in operational terms between the 5 powders. Be concise. Use categories that are mutually exclusive. Recall MOD 102 in which you classified objects using mutually exclusive descriptions.

Using small samples of unknown powders, try to identify them as combinations of two or more of the original powders with which you worked. Give your conclusions and the tests from which they resulted in the space below:

I conclude that X contains powders ______________ because

I conclude that Y contains powders ______________ because

I conclude that Z contains powders ______________ because

MOD 162 Planets and Bright Stars in the Current Sky
Communicating, inferring

PREREQUISITE: An introductory session will be given by the instructor for the students who choose this MOD. This will include a lecture on magnitude scale and the celestial sphere, and a study session in the planetarium.

OBJECTIVES:

1. Using the celestial globe, you will estimate the right ascension of several bright stars to the nearest 4 minutes and the declination to the nearest degree. Compare these estimations with the values given in tables provided by the instructor.
2. You will mark on the celestial globe the positions of the sun and the naked-eye planets for a given observation day. The instructor will provide the coordinates required. Given the time of sunset for this day, you will estimate the time of rising and setting of each naked-eye planet and its time of transit of the meridian.
3. Using the celestial globe and observing the real sky, you will answer correctly the questions on the following pages.
4. Given observation of Polaris in the north, you will write down a method of estimation for position of the celestial equator in the night sky.
5. Given the planetarium pointer, you will point out on the planetarium ceiling and name the following stars and constellations:
    a) Polaris, Betelgeuse, Rigel, Sirius, Pollux, Castor, Capella, Aldebaran, Deneb, Vega.
    b) Big Dipper, Little Dipper, Cassiapeia, Cepheus, Orion, Canis Major. Gemini, Auriga, Taurus, Lyra. Show outlines as given on star maps.

INSTRUCTIONAL REFERENCES & MATERIALS

1. Levitt and Marshall, Star Maps for Beginners
2. Celestial globe, masking tape, a flexible transparent scale
3. Astronomy textbooks
4. Maryland Academy of Sciences, The Graphic Time Table of the Heavens, annual publication
5. Nova-3 planetarium projector(a demonstration showing by the instructor)

FINAL ASSESSMENT:

1. See objectives above.
2. Report to the instructor with the globe set for the latitude of your location and with the sun and planet tape marks in place.
3. Bring your flexible scale.

PROCEDURE:

Terms Necessary for this MOD

CELESTIAL SPHERE: The apparent sphere on which the celestial bodies appear projected. The position of the observer is at its center. As a result of the earth's rotation from west to east, the celestial sphere seems to turn from east to west.

ZENITH: The point on the celestial sphere above the observer which is directly opposite the direction of gravity.

NADIR: The point on the celestial sphere below the observer which is in the same direction as the direction of gravity.

GREAT CIRCLE: Any circle which bisects the celestial sphere.

HORIZON: The great circle on the celestial sphere 90° from the zenith. For an observer, the horizon is commonly called the line where the sky meets the earth.

VERTICAL CIRCLE: Any great circle which passes through the zenith. It also is any great circle at right angles to the horizon.

CELESTIAL MERIDIAN: The great circle which passes through the zenith and the north and south points of the horizon.

COORDINATE: In mathematics, any magnitude of a system of two or more magnitudes used to define the position of a point, line, curve, or plane. On the celestial sphere, two numbers, or coordinates, are needed to uniquely specify any point.

HORIZON SYSTEM OF CELESTIAL COORDINATES: The celestial object is located on a hemispherical sky that is fixed and determined by the observer's horizon and zenith. The two coordinate numbers are altitude and azimuth.

ALTITUDE AND AZIMUTH: Refer to the discussion of these terms in an astronomy text.

CELESTIAL EQUATOR: The projection of the earth's equator onto the celestial sphere.

CELESTIAL NORTH AND SOUTH POLES: The projections of the earth's north and south poles, respectively.

EQUATORIAL SYSTEM OF CELESTIAL COORDINATES: The celestial object is located on a spherical sky that moves and that is determined by the orientation of the earth's poles and of the equator in space. The two coordinate numbers are declination and right ascension.

DECLINATION AND RIGHT ASCENSION: Refer to the discussion of these terms in an astronomy text.

HOUR CIRCLE: A great circle in the equator system which passes through a specified point on the celestial sphere and the celestial pole. Hour circles are the same as circles of right ascension. Both are half-circles from pole to pole. Hour circles may be considered as fixed either on the turning celestial sphere or fixed with respect to the observer, as is the case with his celestial meridian.

CELESTIAL GLOBE: A model of the celestial sphere.

Most of these definitions and the following activities have been adapted from activity and observation sheets constructed by R.C. Victor, Abrams Planetarium, Michigan State University.

Before you begin, locate the following on the celestial globe:

Key to symbols indicating brightness of stars
North celestial pole
South celestial pole
Celestial equator
Parallels of declination
Hour circles or circles of right ascension
Horizon - Zenith - Nadir
Meridian circle - note two different scales on it; what do they measure?
Constellation outlines
Constellation boundaries
Ecliptic

In the following pages, "today" and "tonight" refer to ________________
(date)

---

1. Using a small piece of masking tape, carefully mark the position of the sun and the naked eye planets on the celestial globe. Write only on the tape, not on the globe. One letter or symbol will identify the celestial object you locate. The following table of coordinates applies to _________(date).

Celestial Object	Astrological Symbol	Right Ascension	Declination
Sun	☉		
Mercury	☿		
Venus	♀		
Mars	♂		
Jupiter	♃		
Saturn	♄		

Set the globe for the latitude of your city (Murray-36.5°N) and rotate it until the sun is at its setting position for the day of __________.

On this day, sunset occurs at __________C.S.T. At sunset time, which hour circle is at the meridian? _____h _____m. At one hour after sunset time, which hour circle is at the meridian? _____h _____m.

2. Discuss with the instructor involved the present positions of the planets visible at this time. Use this information for #3 below.

What is the azimuth and altitude of the sun at sunset today?

______________________ and ______________________

3. **Which planets are above the horizon at sunset today? These planets are called "evening stars." Give their altitudes and azimuths at sunset.**

Planet	Altitude	Azimuth

4. **Advance the globe to a position corresponding to one hour after sunset. At this time the sky is dark enough for ovservation. Without stating values of altitude and azimuth, describe in your own words where you would find every planet visible at that time.**

5. **Describe where the Big Dipper is one hour after sunset "tonight."**

6. Make a sketch of the Big Dipper as it appears on the celestial globe and another sketch as it appears on a star map. Sketch also its appearance in the real sky. Explain the chief differences in the sketches.

7. List all first magnitude stars which are visible at 7:00 p.m., C.S.T. and describe their approximate locations. Be accurate enough so that an observer would be able to find them, and also give their azimuths and altitudes.

Star	**Approximate Location** **Direction** (Azimuth)	**Distance above Horizon** (Altitude)

8. Advance the globe until the sun is at its rising position. Does the sun rise exactly in the east "tomorrow?" Where does it rise?

9. Which planets are above the horizon at sunrise? Thes[illegible]lled "morning stars."

10. Without using values of altitude and azimuth, tell where you would look for the above planets one hour before sunrise.

11. List all first-magnitude stars visible one hour before sunrise and describe their approximate locations. Be accurate enough so that another observer would be able to find them, and also give their azimuths and altitudes.

Star	Approximate Location Direction (Azimuth)	Distance above Horizon (Altitude)

12. Give the name of the constellation which currently serves as a background for each of the following:

Venus ____________________ Mars ____________________

Jupiter ____________________ Saturn ____________________

13. **Read the right ascension and declination of 8 of the first-magnitude stars from the globe. Compare your readings with the values given in astronomical tables. There are 15 such stars visible from locations at 45°N latitude.**

Star	**From Globe**			**From Tables**	
	R.A.	**Decl.**		**R.A.**	**Decl.**

MOD 163 Linear and Angular Measurement
Determining circumference-diameter relationships of circular objects

"Relatvie motion, directions, angles and certain other concepts occur early in the SAPA hierarchy for using distance relationships. Later in the SAPA sequence . . . the principle of rate of change occurs frequently. This includes rate of change of position, rate of growth of a plant, angular speed and others."

OBJECTIVES:

1. Given the materials listed below, complete the following exercises. You will state a rule relating the diameter and circumference of a circular object.
2. Given its angular speed and its radius or diameter, you will state and apply a rule to find the linear speed of a rolling wheel.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Measurement, Activity 7
2. Thread
3. Circular objects of your choice such as lids, cups, and bottles
4. Reading supplement, page 3 of this MOD
5. Ruler
6. Compasses

FINAL ASSESSMENT:

Bring your data sheets to the instructor and be prepared to discuss your data and describe or perform any of the activities in this MOD.

PROCEDURES

1. Do Activity 7, Items 1, 2, 3, (draw seven circles of different size). 4, 5, 6, 7, and 8 in MMP, Measurement.
2. Select one of the circular objects from activity 1 and use its diameter to measure at least 5 distances in the room such as the length of a table. Take the same circular object and measure these same 5 distances by using the circumference. Record your data below.

	OBJECT	DIAMETERS	ROTATIONS
1.			
2.			
3.			
4			
5			

State and apply a rule relating the circumference and diameter of a circle.

DEFINITION FOR ANGULAR SPEED

If the radius of a circle revolves at a uniform rate in a plane about its center, the angle through which it revolves in a unit of time is called its angular speed. The distance a point on the circumference (where the radius ends) moves in a unit of time is called its linear speed.

The angular speed of the second hand of a watch = $360^\circ = 2\pi$ radians = 1 revolution perminute. If the hand (radius of the circle) is .5 inches in length, the linear speed of its tip (point on the circumference) is $2\pi(.5) = \pi$ inches = 3.14 inches perminute. Therefore, the linear speed of a point at the end of the radius is equal to the angular speed times the radius.

EXAMPLE:

The rear wheel of a wagon has a radius of 2.5 feet and is revolving at 16 revolutions per minute. What is the linear speed of a point on the rim in miles per hour?

Solution:

1. 16 revolutions = $16(2\pi) = 32\pi$ radians since there are 2π radians in 1 revolution.
2. Linear speed = $32\pi(2.5) = 80\pi$ feet per minute.
3. Linear speed = $80\pi(60) = 4800\pi$ feet per hour since there are 60 minutes in 1 hour.
4. Linear speed = $\frac{80\pi \cdot 60}{5280}$ miles per hour, since there are 5280 feet in 1 mile.
5. Linear speed = $\frac{4800\pi}{5280}$ miles per hour = $\frac{10\pi}{11}$ = 2.86 miles per hour.

3. Fill in the table.

Radius	Angular Speed	Linear Speed
5.28 cm	.376 radians/minute	
2.376 feet	4.108 radians/hour	
.135 m		.812 m/min
13.[illegible] cm		34.8 cm/min
	3.13 revolutions/min	59 inches/min
26 miles	3 radians/ hour	78 miles per hour

MOD 164 Models for Celestial Motions
Predicting, using space-time relationships

OBJECTIVES:

1. Given a direction for the sun's rays and youself acting as the earth, you will demonstrate rotation of the earth, sunrise, midday, sunset, and midnight. Given various objects to represent moon, planets, and stars, rotate and demonstrate their rising and setting.
2. Given objects in the room as sun and stars and yourself acting as the earth, you will demonstrate the revolution of the earth about the sun, the apparent west-to-east motion of the sun through the stars, and the seasonal change of constellations.
3. Given a direction for the sun's rays, an object in the room as a moon and yourself acting as the earth, you will demonstrate the revolution of the moon about the earth and the times of moon rise and moon set for the various phases of the moon.
4. a. Given an object in the room as a sun and a person as one of the inferior planets inside the earth's orbit, and youself acting as the earth, you will demonstrate the appearances of the planet east or west of the sun, as an "evening star" or "morning star," respectively. You will indicate positions of superior and inferior conjunction and of maximum elongation.
   b. Given an object in the room as a sun and a person as one of the superior planets outside the earth's orbit, and yourself acting as the earth, you will demonstrate the following phenomena: conjunction, quadrature, opposition, and retrograde motion.
5. You will describe an alternate way of demonstrating any one of the celestial motions mentioned in objectives 1-4 using simple material objects.

INSTRUCTIONAL REFERENCES & MATERIALS:

This MOD, pp. 2-7

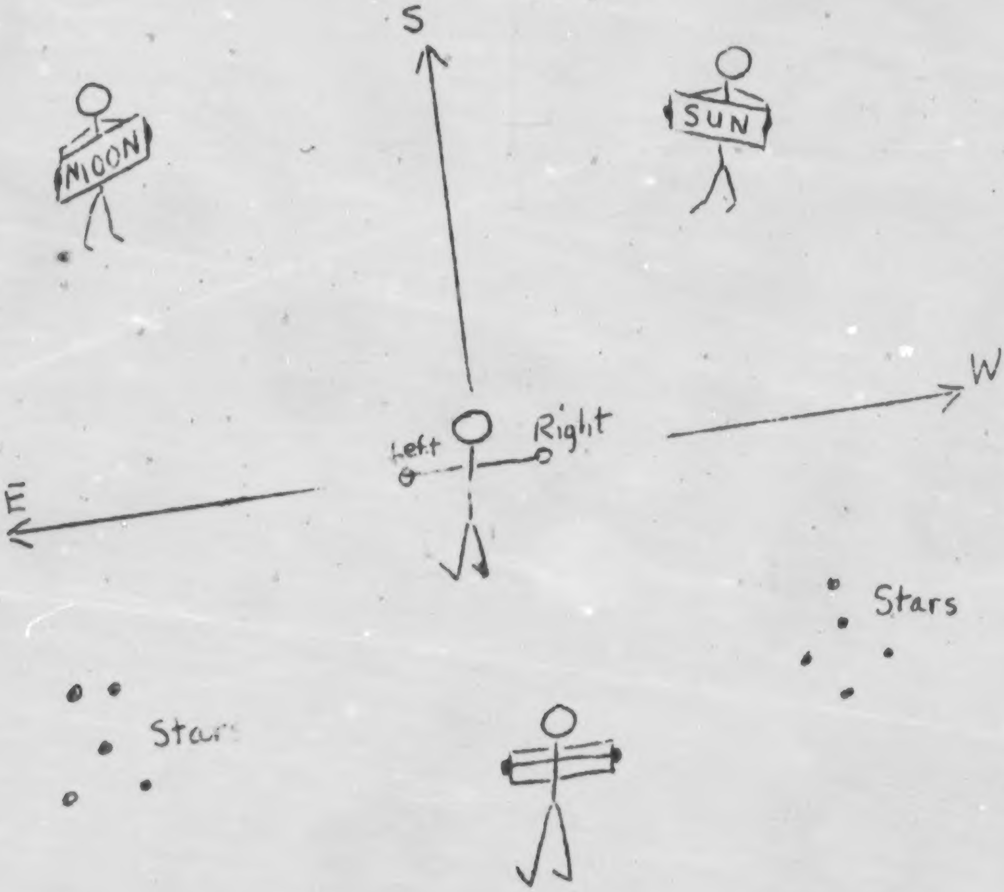
FINAL ASSESSMENT:

1. Be prepared to demonstrate the motions described in objectives 1-4 as your instructor indicates objects in the room that represent celestial bodies.
2. See objective 5.

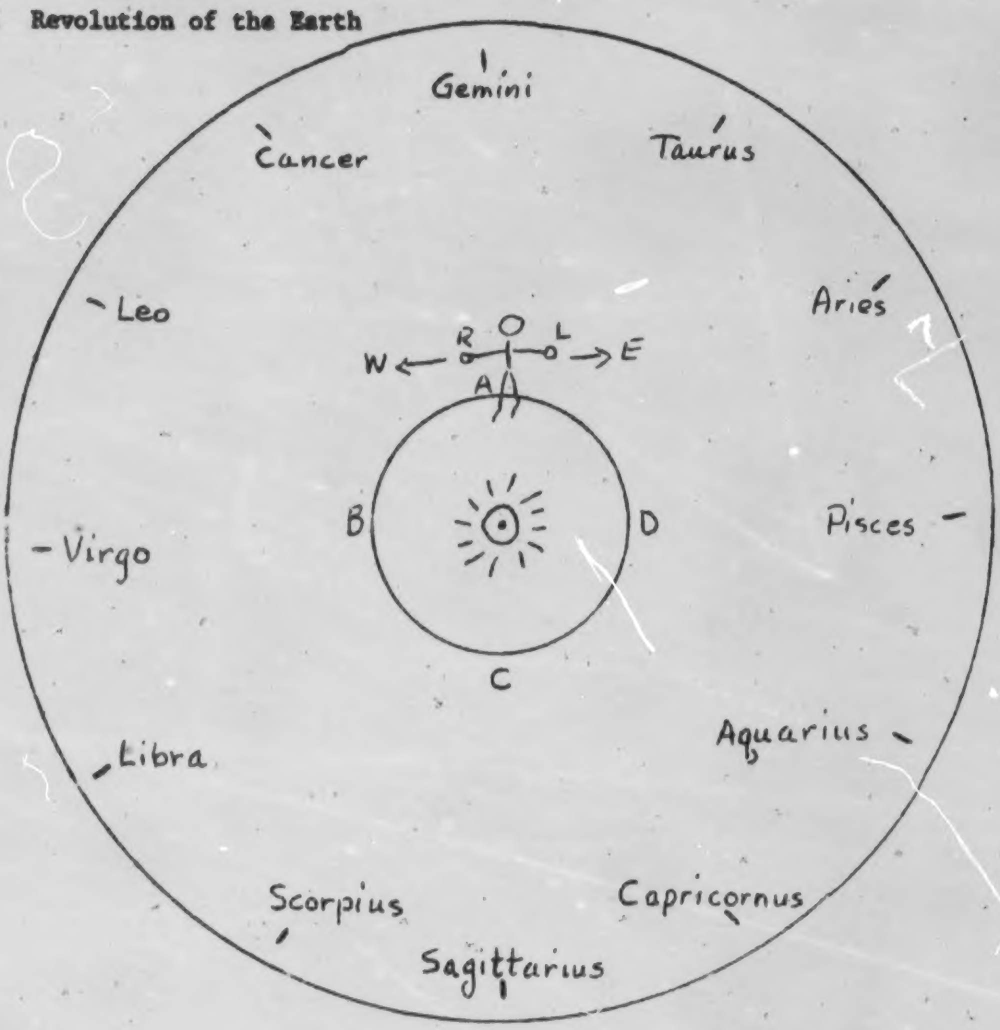
PROCEDURE:

1. Rotation of the earth

Let various persons or objects around the room represent the sun, moon, planets, and stars. You represent an observer on the rotating earth. Slowly "rotate" counterclockwise with your arms extended straight from your sides. Your left arm indicates the direction toward the eastern horizon and your right arm indicates the western horizon. With the directions of west and east dependent upon your right and left sides, south and up will always be the way you face while north and down will always be at your back. For example, if you begin as in the diagram, the moon appears in your southeastern sky and the sun appears in the southwest. As you turn one-eighth (1/8) of a circle, the moon seems to move from southeast to south. The sun seems to move from southwest to west where it sets at the position indicated by your right arm. Continue the rotation so that all of the objects in the sky appear to rise and to set. Note especially the positions that correspond to midday and midnight.



2. Revolution of the Earth


Gemini
Cancer
Taurus
Leo
Aries
R
O
L
W
E
A
B
D
Virgo
Pisces
C
Libra
Aquarius
Scorpius
Capricornus
Sagittarius

The earth's revolution in orbit around the sun makes the sun seem to move from west to east through the zodiac over each year. This explains why evening constellations change with the seasons.

Represent an observer on a rotating earth as in the demonstration of activity 1. Revolve about another person or object representing the sun in a counter-clockwise direction in a small "orbit." Represent the constellations of the zodiac with 12 objects or signs around the room. Make this circle as large as possible. Let it uniformly surround the orbit of the earth.

Pick one location, A, in the earth's orbit. Then rotate in place counterclockwise at this spot. Describe what you see in your sky. Consider the observer in the diagram. As he looks toward the sun in front of him, he sees it against the background of summer stars. The winter stars appear opposite the sun in his evening sky. Therefore, the season is winter. As he sees the sun go down in his west, he sees Gemini come up in his east. At midnight when the sun is directly behind him, he sees Gemini in his south, Leo in his east, and Pisces in his west. The observer revolves to position B, watching the sun as he goes. It will seem to him that the sun moves through the constellation Sagittarius, to Capricornus, to Aquarius, to Pisces. In his sky, this is a west-to-east motion of a quarter circle corresponding to the quarter revolution he made. At B, the observer sees the sun against autumn stars by day. In his evening sky, he sees the spring stars. Thus, the season is spring.

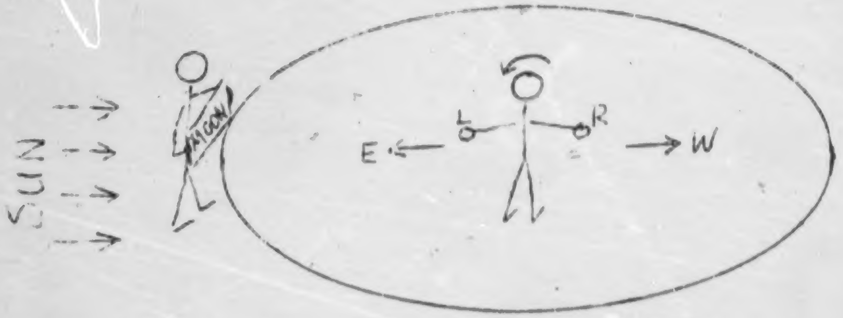
Next, let the observer revolve to position C, then to D, and finally back to A. The sun apparently will have made a complete west-to-east circle through the zodiac. The constellations will have made their apparent annual east-to-west trip across the observer's sky.

3. The Changing Shape and Positions of the Moon

As an observer on a rotating earth, let your extended left arm determine the direction of the eastern and your extended right arm determine the direction of the western horizon. With this convention you can demonstrate the reason for the moon's phases. You can also obtain approximate times of moonrise and moonset in terms of sunrise, midday, sunset, and midnight. You need one object as your stationary sun and another object as your revolving moon. As rotating earth you will turn in place, that is, you will not revolve about your sun. The diagrams illustrate how you will perform these demonstrations. Assuming that sunrise is 6 a.m. and sunset is 6 p.m., the estimations obtained in the activity below serve as approximations of actual moonrise and moonset.

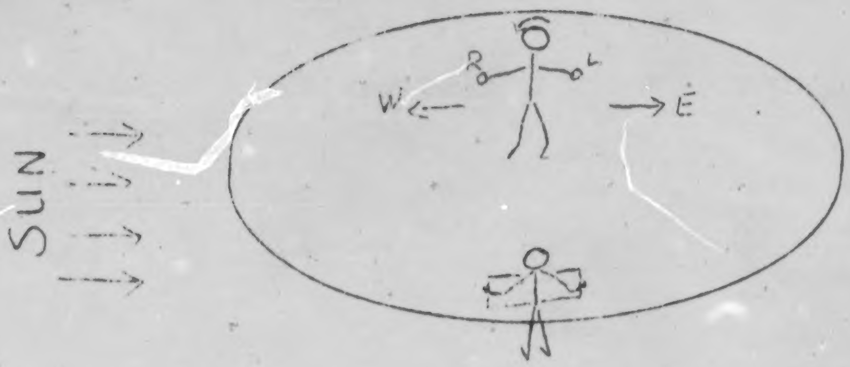
New Moon

Earth rotates in place in a west-to-east direction once in 24 hr., or it rotates each quarter revolution in 6 hr.



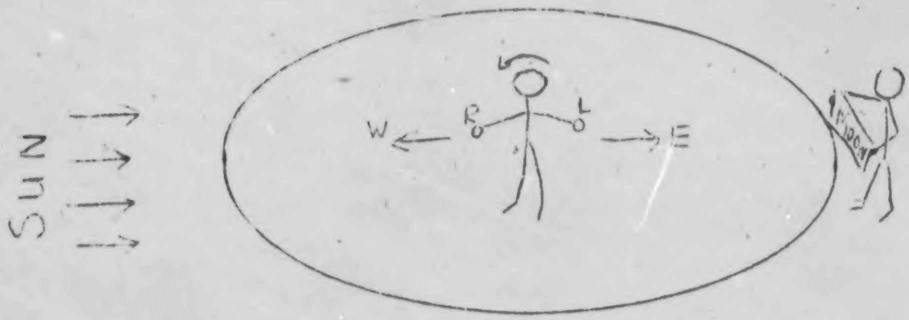
The sun and moon appear to come up together. As the earth rotates, the sun and moon seem to pass across the south and then go down together. That is, the new moon rises at sunrise and sets at sunset.

First Quarter



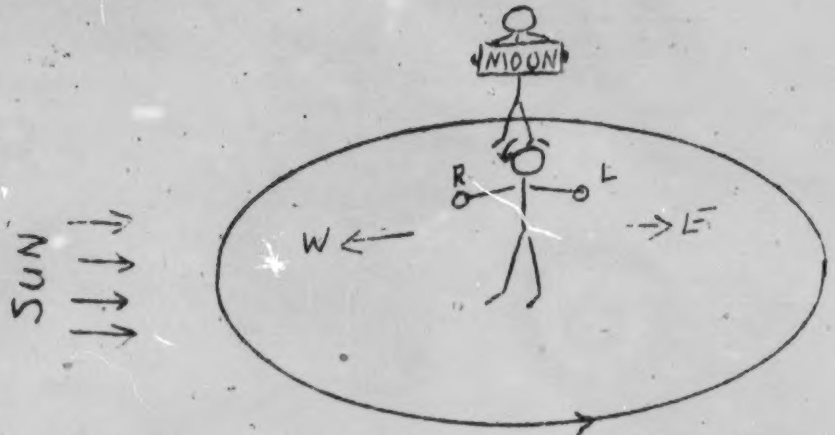
As the sun sets at the observer's western horizon, the first quarter moon is in the south. As earth you face the direction in which the observer faces. After a quarter turn, about midnight, the moon sets. At this point, the sun is directly behind the observer. Another quarter turn will bring the sun to the observer's eastern horizon. The moon rises for the observer a quarter turn after sunrise. This occurs when the observer sees the sun in his south, or directly in front of him. That is, the first quarter moon rises at approximately midday.

Full Moon



As the observer sees the sun disappear at his western horizon, he sees the moon appear at his eastern horizon. That is, the full moon rises at sunset time. After a quarter turn, or at midnight, the moon in in his southern sky when the sun is directly behind the observer. Another quarter turn brings the sun over the observer's eastern horizon and the moon will set at his western horizon. That is the full moon sets at sunrise time.

Last Quarter

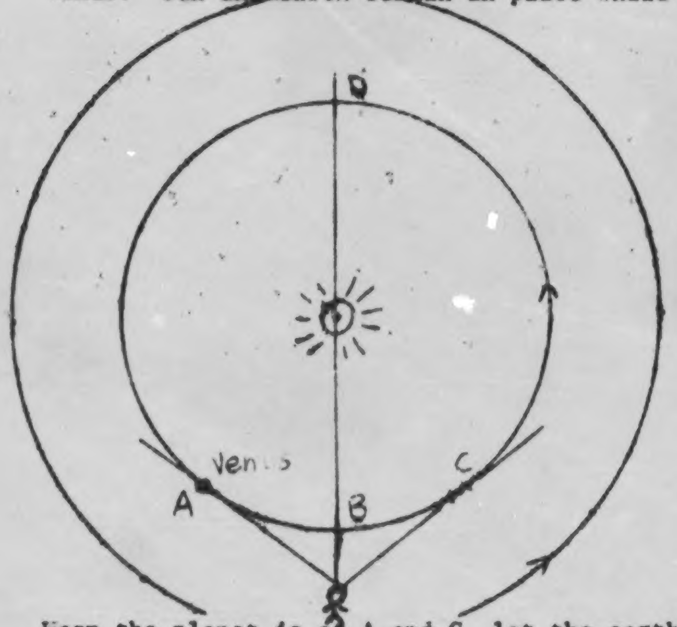


At sunset time, as the sun disappears over the western horizon, the moon is not in the observer's sky. After a quarter turn, at midnight, the moon appears at the observer's eastern horizon. That is, moonrise for the last quarter occurs approximately at midnight. At sunrise time, the moon is in the observer's south. At midday, the moon disappears over the western horizon. That is, the last quarter moon sets approximately at midday.

4. Apparent Motions of the Planets

A. Inferior Planets. Refer to the Diagram.

Let three persons represent sun, earth, and inferior planet of Mercury or Venus. Sun and earth remain in place while the planet revolves about the sun. The observer on earth sees the planet move from one side of the sun, A, to the other, C, and back again. The planet will seem larger but less of its illuminated face will be seen as it moves from A to B to C. It will show none of its illuminated surface when it is exactly between earth and sun (B). As the planet travels from C to D to A, it seems smaller, but more of its illuminated face can be seen from earth.

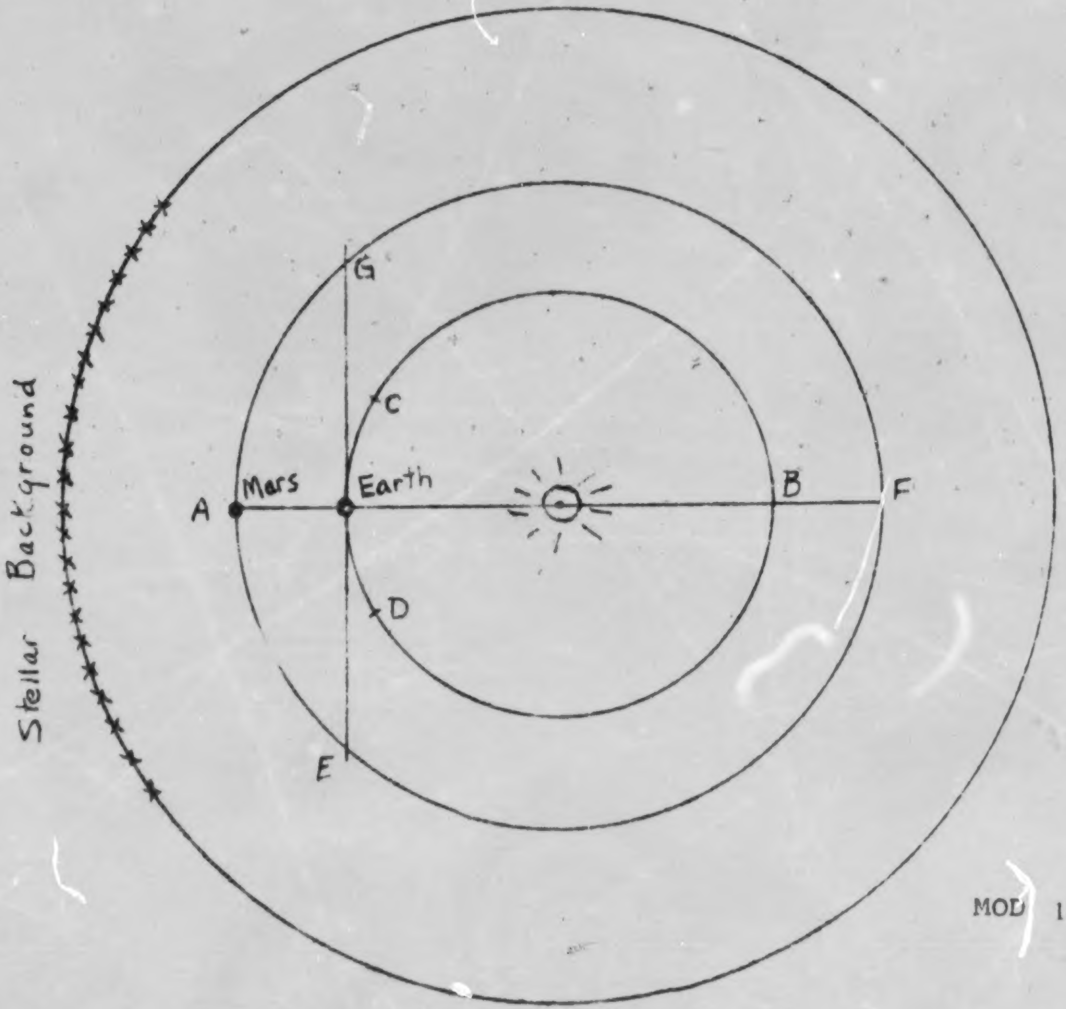


The aspects of the planet are:
A - maximum eastern elongation
B - inferior conjunction
C - maximum western elongation
D - superior conjunction

When the planet is at A and C, let the earth-person rotate and determine whether the planet is seen in the west as an "evening star" after sunset, or in the east as a "morning star" before sunrise.

B. Superior Planets. Refer to the diagram.
Let three persons represent sun, earth, and a superior planet, for example, Mars. Earth and Mars, a superior planet, revolve in orbit in such a way that earth completes approximately two revolutions while Mars completes one. Fix Mars in its orbit at one place (A). As the earth-person moves from B to C, Mars apparently moves in the observer's sky from west to east in direct motion. When earth is at C, Mars apparently stops and reverses its motion so that it seems to travel against its background from east to west for a time in retrograde motion. When earth reaches D, Mars again seems to stop and then it resumes its apparent west-to-east motion as the earth travels from D to B. You may wish to represent both planets in motion since both planets actually revolve at all times around the sun. The same demonstration of retrograde motion is possible, provided earth's revolution rate is about twice that of Mars.

The aspects of a superior planet are:
A - opposition
E - western quadrature
F - conjunction
G - eastern quadrature



MOD 165 Measurement of Length, Area, and Volume

OBJECTIVES: At the conclusion of this MOD you should be able to:

1. Make accurate linear measurements in metric units.
2. Determine area of a region by covering the region with standard units.
3. Use formulas to compute the areas of regular-shaped regions.
4. Recognize and name units of linear, area, and volume measures.
5. Use a geoboard to illustrate area and perimeter problems.
6. Measure the volume of regular and irregular-shaped containers.
7. Calculate the volume for regular-shaped containers.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. MMP, Measurement
2. Scissors, paper, grids, geoboards, dot paper, rubber bands, construction paper, Dienes blocks, Cuisenaire rods, cans, transparent containers, rectangular containers, water

INSTRUCTIONS:

In the MMP, Measurement read "Certain Common Measurements," pp. 31-32 and then complete the questions or exercises for the following:

(Do not cut, tear, or write in the book.)

Activity 4: Items 1, 2, 4 , 5 , and 6
Activity 5: Items 1, 2, 3, 4, 7 and 8

Activity 6: Items 1, 2, and 3
Activity 8: Items 1, 2, 3, 4, 6 , and 7

FINAL ASSESSMENT:

1. Bring all papers to the evaluation session.
2. Be prepared to discuss work and responses with the instructor.
3. See objectives.
4. Be prepared for a written test as a part of your evaluation.

MOD 166 Compasses and Magnetic Fields
Observing, inferring, interpreting data

OBJECTIVES:

1. Given a compass, you will point out the approximate directions of N, E, S, W.
2. a. Given a bar magnet and a bobby pin, you will magnetize the bobby pin and make a compass from it by suspending it from a string.
   b. Given a needle and a bar magnet, you will magnetize the needle and make a compass from it by floating it on aluminum foil in water.
3. Given bar and horseshoe magnets, iron filing, and paper towels, you will sprinkle iron filings on paper placed over the magnet to obtain patterns of lines of force about a magnet.
4. Given a bar magnet, a small compass, and a wooden pencil, you will plot the lines of force that result from the earth and the bar magnet combined.
5. Given a sealed "magnet box," a small compass, and a large piece of paper, you will plot the magnetic field surrounding the magnet box and interpret the data in order to locate the north pole and the south pole.
6. Given magnets, iron filings, and paper, you will work out an arrangement of magnets to make a geometric design or an artistic pattern, as a face or flower, when you sprinkle iron filings on the paper covering the magnets.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Schmidt and Rockcastle, Teaching Science with Everyday Things, p. 111, 114
2. SAPA, 55 & 86, Magnetic Fields.
3. Any physical science text on "Magnetism."
4. Compasses, bobby pins, needles, horseshoe and bar magnets
5. "Magnet boxes" made to conceal the position and orientation of a magnet

FINAL ASSESSMENT:

1. Answer instructor's questions about objectives 1 and 2 above.
2. Present your records and answer questions about objectives 3, 4, and 5 above.
3. Assess your work for objective 6; however, sketch and be ready to describe your results.

PROCEDURE:

1. Take one of the compasses and using a bar magnet test its polarity. Then walk around the room and the adjoining area to observe the needle of the compass. Infer the reasons for its behavior. Try to determine the directions of N, E, S, W.

2. Bobby pin compasses
Spread apart the prongs of a bobby pin so they are at an 180° angle, except for the small center bend. Then hold it by the bend, and stroke the bobby pin about 50 times on a strong magnet. Always in the same direction rub its entire length, from tip to tip, on one end of the magnet only. Keep the other end of the magnet far away from the bobby pin. The bobby pin should be magnetized strongly enough to pick up a paper clip. Next, tie a single, thin thread at the bend of the bobby pin. Hang it up so it can swing freely, at least a few feet away from iron objects, such as pipes or other magnets. If necessary, slide the knot to either side, until the bobby pin hangs level. With the help of a labeled bar magnet, determine the polarity of your compass.

Some of your classmates will be doing this same activity. Have them hang their bobby pin compasses across the room. Is there general conformity in direction?

A compass like this works especially well outdoors if it is shielded from the wind. Experiment outdoors by hanging the magnetized bobby pin in a gallon jar or jug. Then tie the thread to a stick or straw across the top. Next fill the jug with water. Will the compass work as well if the jar or jug is filled with water? Does the bobby pin then swing as much as before? This is why airplane and ship compasses are liquid-filled. (Adapted from Schmidt and Rockcastle, Teaching Science with Everyday Things, p. 111.)

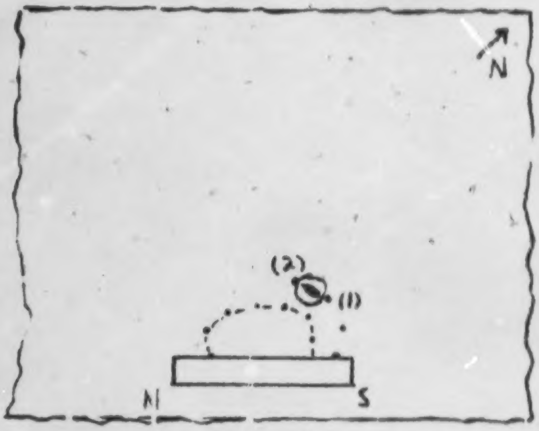
3. Needle poles
Hold a needle by its eye and about 30 times rub its entire length on one end of a strong magnet. Be sure to rub from the eye to the point only, making a wide arc away from the magnet on each return. Next, set a non-iron water container far from any iron or steel objects. Pour in some water and on it float a piece of aluminum foil as large as a quarter. Then lay the magnetized needle on the foil. What does it do? If the floating system is spun around, does it return to the same position each time? How does this position compare with that taken by the bobby pin compasses? Remember whether the eye or the point of the needle points north. Now take this needle off the foil and magnetize another needle. Find and remember which end of this needle points approximately northward. Then float either needle on the foil. Hold the other needle in your hand and bring it close to the needle on the water. What do the like poles do when near each other? The unlike poles? Do the poles of two magnetized bobby pins interact in the same way? What does this indicate about the nature of the magnetic poles located in the earth near the North Geographic Pole? (Adapted from Schmidt and Rockcastle, p. 114)

4. The earth's magnetic poles
Where are the magnetic poles of the earth actually located? Find their latitude and longitude on an earth globe or in a resource book. What kind of tests and observations would you make to confirm this location?

Do not use pencils with metal parts in the following activities.

5. Patterns of lines of force about a magnet
Work over a large sheet of newspaper or wrapping paper. Please do not be careless and wasteful with iron filings. Pour them carefully from the paper back into the jar after you do your work.
If iron filings are sprinkled carefully on a thin sheet of paper placed over a magnet, they will trace the lines of force around the magnet. Try this by putting a paper towel over one magnet or over various combinations of magnets. Tap the paper lightly with a pencil in order to get filings into place quickly. Do this with the bar magnet alone, with the horse-shoe magnet alone, with two unlike poles about one inch apart. On the reverse side of this page, neatly record your results in drawings.

6. Plotting the resultant field of a bar magnet and the earth
Although you may work in pairs, each student must trace a pattern for activities 6 and 7.



Try to find a place in the laboratory or its immediate surroundings where a compass seems to be least affected by surrounding iron such as steel beams in the building or water pipes. This might be a location on the floor. Here set a bar magnet toward the bottom of a large piece of white paper which has been taped down. Draw an outline of the magnet and mark the poles on the paper in case the magnet should be jarred and need to be restored to its original position. Using a compass, mark the direction "North" on the paper with an arrow. Remove the bar magnet when you mark north. Once you begin to plot, do not move the paper or the magnet.

Using a very small compass and a sharp wooden pencil, in the following way, plot lines of force about the upper half of the bar magnet. Set the compass near one of the poles of the magnet so that one of its poles (1) is drawn to the magnet. Mark with a dot the position of the opposite pole and of the compass needle. Move the compass until the first end (1) of the needle points to the dot just made. Mark with another dot the position of the opposite end (2) of the needle. Continue marking points tracing lines of force to the bar magnet or off the paper. Connect the dots made with a smooth curve. Do this for at least four lines of force. Can you account for the lack of symmetry in the resultant curves?

7. Interpreting data obtained from compasses and magnet boxes
Fasten a large piece of brown paper at least 50 cm. square to the table or floor away from iron objects. Draw an arrow on the paper to indicate the direction of magnetic north. Use a compass for this. Take one of the sealed magnet boxes and tape it to the center of the paper. Outline the box. The box contains a bar magnet and will therefore be surrounded by a magnetic field like that surrounding the magnet in activity 6. Using a very small compass in the same way as you did for 6, plot 8 to 10 compass direction lines or lines of force around the box. At least 2 of these lines should lead back to the box, and at least 4 lines should extend to the edges of the paper.

Using careful observation and your ingenuity in interpretation, try to predict where the north and south poles of the magnet are. After you have reached your conclusion, clip the box open without removing the tape that holds it to your paper and check your prediction. Be ready to report two methods that you used to determine the polarity of the magnet in the box. One of these methods involves the lines that go off your paper. Then re-seal the magnet boxes so they are ready for the next student.

MOD 167 Preparation and Peer Teaching in Science
(an individual activity)

This MOD is designed to allow you to develop a lesson in science appropriate for elementary children and to refine your understanding and skill with the lesson with a group of your colleagues.

OBJECTIVES: After completing this MOD you should be able to identify some of your weaknesses and strengths in understanding and teaching the selected material and should be able to revise your plan to reinforce the strengths and improve weaknesses.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Films: "Don't Tell Me, I'll Find Out" and "What Would Happen If"
2. Manuals and Guides in the SMERC
3. Materials in the SMERC
4. Videocasette recorder and television
5. "General Methodology Competencies for the Preservice Teacher in Elementary Science" from MOD 127, p.2

INSTRUCTIONS:

1. View the two films of SCIS classrooms.
2. Utilizing concepts or processes that you have covered in the ISMEP program, develop an inquiry lesson appropriate for an elementary class. Include in the plan at least the following topics:

   TITLE
   OBJECTIVES
   MATERIALS NEEDED
   INTRODUCTORY ACTIVITIES
   PROCEDURES
   EVALUATION PLAN

3. Submit, in good form, a copy of your plan to the instructor.
4. After the plan has been approved, teach it to at least three ISMEP students while filming on videocasette.
5. View your casette with the ISMEP students and a faculty member or graduate assistant. Utilize feedback to improve the lesson.

FINAL ASSESSMENT:

Successful completion of the MOD will have been achieved when the MOD has been completed with integration of feedback into the final revision of the plan and you and the faculty member consider the lesson ready to teach to children.

MOD 168 Measurement for Elementary Schools

PREREQUISITES: MODs 160, 163, and 165

In MODs 160, 163, and 165 the emphasis was primarily on your learning about measurement. In this Mod you will focus directly on child learning. You will be learning about activities, techniques, and problems associated with child learning of measurement.

OBJECTIVES: At the conclusion of this MOD you should be able to:

1. Describe what Piaget means by "conservation" and be able to give examples or illustrations.
2. Analyze anecdotes of children's measurement responses to diagnose the child's source of difficulty.
3. Identify some difficulties that children might have with certain measurement tasks.
4. Develop a logical sequence for a measurement topic throughout the elementary school.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. MMP, Measurement
2. Scissors, square-centimeter graph paper, large sheets of plain paper, tape measure, base 2 and base 3 blocks, sheets of cardboard with string configurations glued on, metric bathroom scales, masking tape, string, plastic beakers, colored chalk, clay, sand
3. Current elementary mathematics text series

INSTRUCTIONS: In the MMP, Measurement, answer questions or perform the exercises for the following:

Activity 12: Read "Focus" and "Discussion" and do Item 1, Read "Discussion" in Item 2, and do Items 3 and 4.
Activity 13: Do Items 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.
Activity 14: Do Items 1B, D, E, G, H, I, and 3.
Activity 15: Read "Focus" and "Discussion" and do Items 1, 2, 3, and 4.
Activity 16: Do Items 1, 2, and 3.

FINAL ASSESSMENT:

1. Bring all papers to the evaluation session.
2. Be prepared to discuss the exercises and your responses.
3. See objectives.

MOD 169 Teaching Science to Elementary Children

PREREQUISITES: MOD 167

OBJECTIVES: At the conclusion of this MOD you should be able to identify some of your strengths and weaknesses in teaching an inquiry lesson to elementary children.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Plan developed in MOD 167
2. Materials from MOD 167
3. Videocasette (tentative)
4. "General Methodology Competencies for the Preservice Teacher in Elementary Science" from MOD 127, p. 2

INSTRUCTIONS:

1. At the scheduled time you will be able to teach the lesson to a group of 4-6 elementary pupils in an area school.
2. Following the teaching experience, you should schedule a session with an instructor and the ISMEP students that you worked with on MOD 167. The teaching experience will be reviewed at that seminar. The faculty member and other ISMEP students will assist in evaluating strengths and weaknesses of the performance.
3. During the seminar a written evaluation should be developed listing strengths, weaknesses, and recommendations for improvement.

FINAL ASSESSMENT:

The MOD will be considered completed following the scheduled seminar and with the submission of the written evaluation.

MOD 170 Interpreting Data (SAPA)
Randomness and probability

INTERPRETING DATA

"The process of Interpreting Data includes many behaviors such as recording data in a table, constructing bar and line graphs, making and interpreting frequency distributions, determining the median, mode, mean, and range of a set of data, using slope to interpret graphs, constructing number sentences describing relationships between two variables, and so on....Interpreting data requires going beyond the use of skills of tabulating and graphing to ask questions about the data which lead to the construction of inferences and hypotheses, and the collecting of new data to test these inferences and hypotheses." SAPA, Supplement to the Guide for Inservice Instruction, p. 25.

OBJECTIVES:

1. Given a list of ten items in a paper bag which feel identical to your sense of touch, you will be able to state the probability of removing any one item with your eyes closed.
2. After doing activity 1 and collecting and analyzing your data, you will be able to make positive statements about the laws of chance and the variables affecting those laws.
3. Having collected your data in activity 2, you will determine the mean, median, mode, and standard deviation for the leaf sizes.
4. Given a probability value for a given event, you will be able to state verbally the chances of that event happening again.
5. Given the probability values for two independent events, you will be able to determine the probability of both events occuring as a unit.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. The pages of this MOD
2. Millimeter ruler
3. Plant with leaves
4. Crow, James, Genetics Notes, pp. 21-23, 143-148, in Resource Center
5. Stanley, John, Essence of Biometry

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

Randomness, Probability, Standard Deviation:

If you were asked this morning what the chances were that you would come to class X today, you might have said, "Chances are about 80%." If you were also asked about the chances that you would be on time, you might have added that the probability of being on time was also about 80%. To you 80 percent chance might mean that your chance of going to class and being on time were good. To anyone interpreting your terms mathematically it would mean the same, but it also would imply that in the past, 20 times out of every 100 times you either missed class or were late if you did come. From the above data one could also say that the probability for you of coming to class and being on time is 64% (.80 x .80 or .64 = 64 percent).

Assume that you are in a dormitory room located in the center of a complex of buildings having identical classrooms. You are alone and you wish to go to one of the classrooms. The classrooms are all alike, all are the same distance from the dormitory room, and there are no other factors to influence your selection. You find yourself making a random selection of the classroom. Should there be 100 classrooms, each room would have the same chance of 1/100 (one in a hundred) that you would pick a particular room.

Alter this situation to imagine there were 20 students each selecting a classroom. As students make a random selection, they may be influenced by a possible clustering of students in one or more of the classrooms. One might find that 10-15 students are in one room, several others have picked rooms near by, others may have picked rooms further away. This is a clustering or a central tendency of the students. Also there is some dispersion from the central tendency. Students become distributed more sparcely as the distance is increased from the central tendency. This degree of dispersion from the central tendency is called standard deviation.

The key words needed to interpret data in this situation can be more specifically described.

Randomness
A random sample is one taken so that every observation which might be included has an equal chance of being included. One must not select observations by any sort of subjective process in which one says "I shall take this observation, but not that one." Bias or other factors that contribute significantly to the outcome of any trial may not exist.

Probability
The use of the word probable or probably without some numerical value has little meaning other than to indicate that there is a chance stronger than a possibility but falling short of certainty. In using the word probability one must always denote the long run relative frequency of multiple or repeated events. In other words, it is not possible to determine the probability for you of going to a class if you have never gone to class before, or if that is the only time you are going. A numerical value attached to a probability statement makes possible a reasonably accurate prediction as to whether or not

the event will occur. Most often the value assigned to a probability statement is a fraction between 0 and 1. If the event will surely occur, it will have a probability of 1. If it is sure not to occur, it will have a probability of 0. The following formulas may be used.

$$p = \frac{\text{Number of favorable cases}}{\text{Total number of cases possible}}$$

Example: If you tossed a penny ten times, it is possible that it could land with heads up ten times (total number of possible cases).
Because it could land with either heads or tails up, you would expect heads up only five times (number of favorable cases).

$$p = \frac{5}{10} = .5 \text{ (probability value)}$$

Further, if the probability of an event happening is p, and p has a value of 0 to 1, then the probability of it not happening (q) is equal to 1 minus p.

$p = 0$ to 1
$q = 1 - p$ or
$p + q = 1$

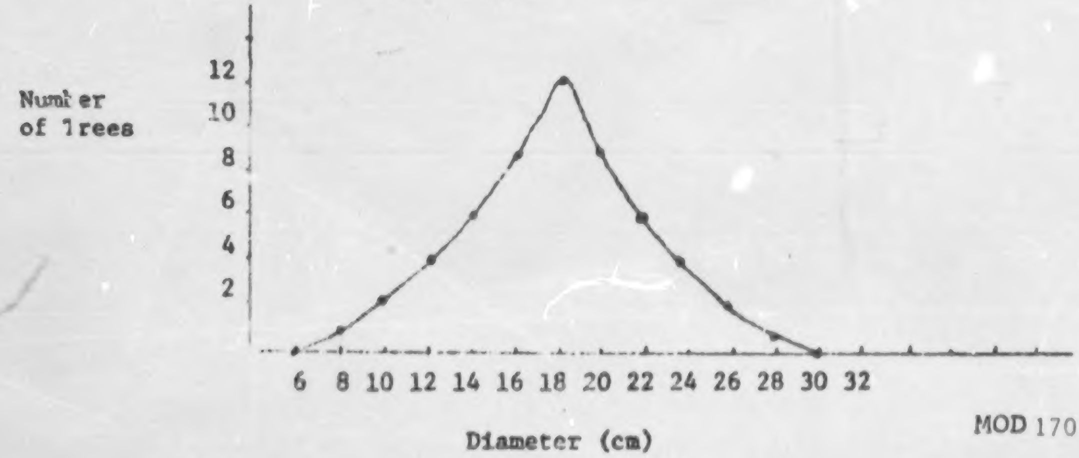
Standard Deviation

The standard deviation is a measure of the central tendency in an array of related data. Or you can say that the standard deviation is a measure of the dispersion (or spreading out) on either side of the mean. The following table of data and the graph will help you understand the meaning of standard deviation as well as other terms or values used in analyzing data.

Analysis of Tree Diameters of 56 Sample Trees

Diameter (cm)	6	8	10	12	14	16	18	20	22	24	26	28	30
Number of trees with a particular diameter	0	1	2	4	6	9	12	9	6	4	2	1	0

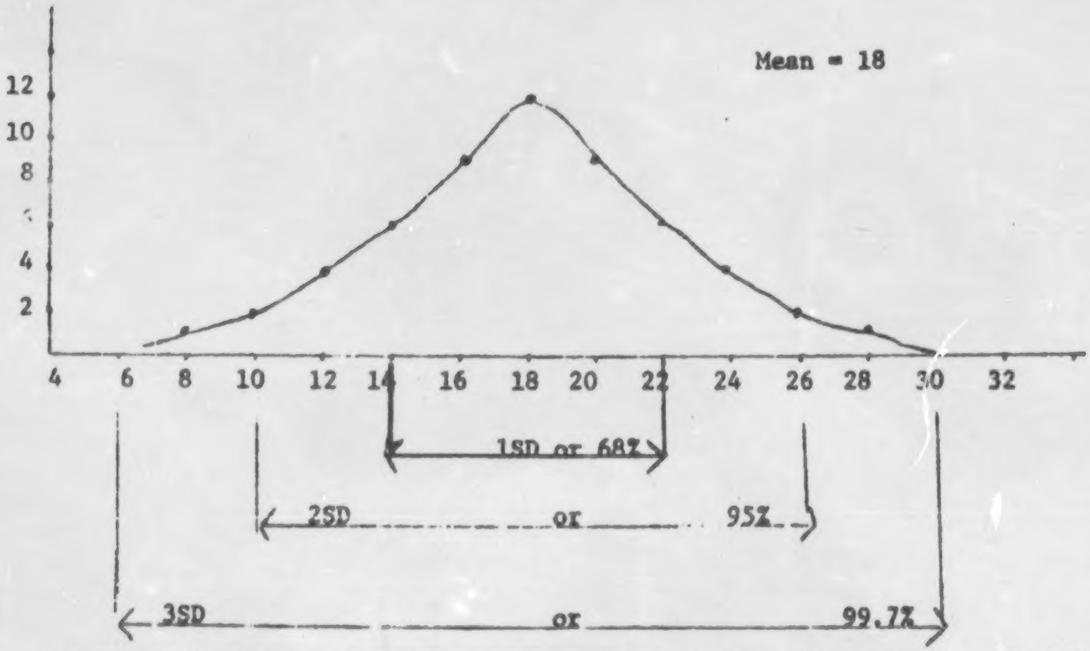
Graph Analysis of Above Data



MOD 170

Total number of observation = 56
Mean Diameter = 18 cm (average size)
Mode = 18 cm (More trees of this diameter than any other)
Median = 18 cm (22 trees have smaller diameters and 22 trees have larger diameters than 18 cm)

In the graph parts of the curve on either side of the mean (18) are equally spaced so that it is a symmetrical curve. Any curve from data which has approximately an equal mean, mode, and median shows a normal distribution or is a normal curve. If we divide the distance from the mean, both to the right and to the left, into three equal parts, we can indicate the data in each part as having a standard deviation of 1, 2, or 3 from the mean. This is shown in the following diagram.



In this analysis, trees with a diameter larger than 14 cm. and smaller than 22 cm. would have a standard deviation of 1 or less from the mean. Also on this curve approximately 68% of the trees would vary from the mean by 1 standard deviation or less. Trees with a diameter 10-14 cm. would not have a standard deviation greater than 2 and less than one. This would include approximately 13.5% of the trees sampled (95 - 68/2) = 13.5% .

If you can answer the following questions, you understand the concept of standard deviation.

1. You are asked to cut only trees with a standard deviation of 0, which trees would you cut?
2. What percentage of the trees in the curve from which the sample was made have a diameter of at least 28 cm?

Activities:

1. Read the following and consider the answer for each probability problem. Some answers are provided.

   A die (singular for dice) has only twos on each side. (How many sides on a die?)

   You throw the die. What is your chance (the probability) of throwing it so that a two comes up?

   Since all sides have twos, the chance of throwing a two would be certainty--we would assign it the number one--the probability of throwing a two would be one.

   Using this same die what would be the probability of throwing a six? 0 chance. It's an impossibility since there are no number sixes on this particular die.

   Let's use a regular die now. This one is numbered from one to six. If we throw this one what is the probability of turning up a three? (1/6)

   If the die is thrown a great number of times about how many of the times will a three turn up? (1/6)

   If a coin is thrown in the air, what is the probability the coin will turn up as a head? (1/2)

   Suppose we throw the die and the coin at the same time: What is the probability of a particular double event such as a tail on the coin and a five on the die coming up in the same throw?

   The coin will show heads 1/2 of the time, and the die will show a five 1/6 of the time. Of all throws of a die and coin simultaneously, the result will be heads on the coin with a five on the die 1/2 of 1/6 of the time, or 1/2 x 1/6 = 1/12 of all double throws. This can be stated in the form of a rule: (Hardin, 1954)

   > Product Rule of Probability--"If a particular double event is composed of two independent single events, both of which must occur in the same instance, the probability of the double event is the product of the separate probabilities of the single events."

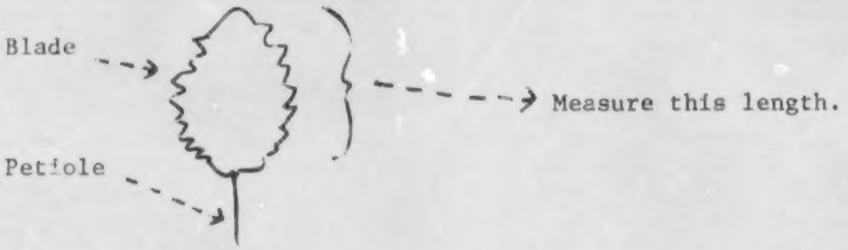
   Let's take another example: Take two pennies together and throw them in the air. What are the possible combinations that could result?
   Ans. HH, HT, TH, TT

   Probability

   1. If you toss a coin which is "unbiased" (i.e., just as likely to fall one way as the other), what is the probability that it will show "heads" rather than "tails?" 1/2
   2. In a toss of an unbiased die (pl. dice) what is the probability that it will turn up one, rather than two, three, four, five or six? 1/6
   3. What is the probability that you will turn up the seven of diamonds on cutting a perfectly shuffled pack of cards? 1/52

4. What is the probability that you will turn up any seven in cutting a perfectly shuffled pack of cards? 4/52 or 1/13
5. If you toss an unbiased coin and an unbiased die at the same time, what is the probability that you will get heads and a three?
6. If you toss two dice what is the probability of getting a pair of threes?
7. If you draw two cards, one after the other, from a perfectly shuffled pack, what is the probability of getting a pair of aces? 1/221
8. If you toss a coin ten times and it turns up heads five and tails five, what is the probability that the next toss will result in heads?
9. If you toss a coin ten times and it turns up heads ten times, what is the probability that the next toss will result in tails?
10. If you toss die A and die B at the same time what is the probability that you will get a five and a six?
11. If you toss two coins at the same time, what is the probability that you will get two heads? two tails? one head and one tail?

2. With a flexible millimeter ruler determine the size of all leaves on a woody plant. Make the measurements as illustrated below.



Measure the leaves to the nearest centimeter using this table.

0 - 1.4 cm = 1 cm
1.5 - 2.4 cm = 2 cm
2.5 - 3.4 cm = 3 cm

Record your data below.

Leaf Size (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number															

Plot your data below and draw your "best line" for the curve.

MOD 171 The Cycle of the Moon
Observing, predicting, using space/time relationships

PREREQUISITE: An introductory session will be given by the instructor for the students who choose this MOD.

OBJECTIVES:

1. Given the moon in the daytime and/or nighttime sky, you will observe and record during one lunar cycle:
    a. its changing shape or phase;
    b. its changing angular distance or elongation from the sun;
    c. its changing stellar background for nighttime;
    d. its changing position with respect to any visible planet;
    e. the total time for one complete cycle (e.g.; from new moon to the next new moon).
2. Given any two of the following, you will give the third:
    a. the moon's phase;
    b. the time of day;
    c. the moon's position in the sky.
3. Given the moon's elongation, you will give its phase, or given the moon's phase, you will give its elongation.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Where is the Moon? Teacher's Guide
2. ESS, Where was the Moon?
3. MOD 171, Study Sheet, pp. 4-5
4. MOD 164,"Models for Celestial Motion", section on the moon's phases
5. Any Introductory Astronomy text - chapter on the moon.

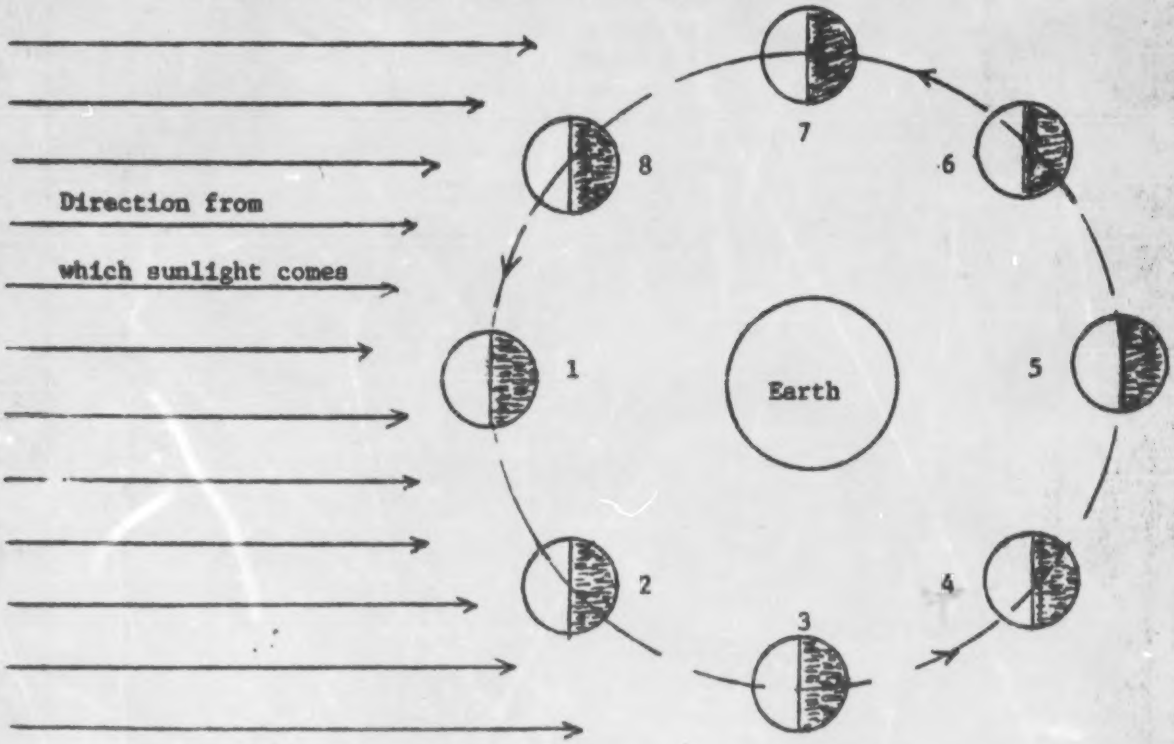
FINAL ASSESSMENT:

1. Test your understanding of the cycle of the moon on Study Sheet, pp. 4-5.
2. Present to the instructor your record of observations of the moon over one month. Refer to ESS, Where is the Moon?, Teacher's Guide.
3. Ask the instructor for MOD 162, Final Assessment, and answer it correctly.

PROCEDURE:

Information Related to the Cycle of the Moon

Phases: The diagram shows the moon in orbit around earth and revolving counterclockwise as viewed from the earth's north pole.


Direction from
which sunlight comes
Earth
1
2
3
4
5
6
7
8

Phases as they appear from earth:

1. New moon (no moon visible)	5. Full moon
2. Waxing crescent	6. Waning gibbous
3. First quarter	7. Last quarter
4. Waxing gibbous	8. Waning crescent

Moon's Elongation: The moon's apparent angular displacement from the sun in our sky is given in degrees of arc, 0° to 180°, and direction, E or W. For example, the first quarter moon (3) has an elongation of 90°E, the waning gibbous moon (6) has an elongation of 135°W.

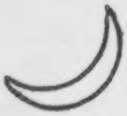
Estimation of Elongation in "Fists": If you extend your arm straight from your body, your fist will subtend about 10° in the real sky. A first quarter moon in the south will therefore be about nine "fists" or 90° to the east of the setting sun at the western horizon.

Moonrise and Moonset:

Phase	Moonrise	Moonset
New Moon	sunrise	sunset
First Quarter	midday	midnight
Full Moon	sunset	sunrise
Last Quarter	midnight	midday

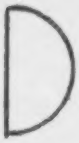
STUDY SHEET

1. The moon has this shape:



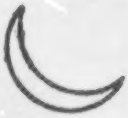
Which of the following best describes its phase?
a) Waxing crescent
b) Waning crescent
c) First quarter
d) Last quarter
e) Gibbous

2. The moon has this shape:



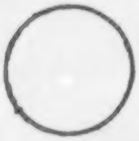
Where would you look for it at sunset time?
a) In the west
b) In the east
c) In the south
d) In the north
e) None of the above could be correct.

3. The moon has this shape:



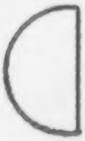
At approximately what time would you see it in the southeast?
a) Sunset time
b) 9:00 p.m.
c) Midnight
d) 3:00 a.m.
e) Sunrise time

4. The moon is in the south and has this shape:



What time is it?
a) Sunset time
b) Midnight
c) Sunrise time
d) Midday
e) None of the above could be correct.

5. The moon has this shape:



What is its elongation?
a) 45°E
b) 90°E
c) 135°E
d) 45°W
e) 90°W

6. Give the most accurate elongation of the full moon.
a) 360°
b) 180°
c) 90°
d) 45°
e) 0°

7. You see the moon in the southeast at 3:00 p.m. At what phase is it?
   a) Waxing gibbous
   b) First quarter
   c) Waning gibbous
   d) Last quarter
   e) None of the above could be correct.

8. Given a star background called Y. Let X represent stars to the left of Y and Z represent stars to the right of Y. Let V represent stars above Y and W represent stars below Y. If on Tuesday at 8:00 p.m. the moon is in Y, on Wednesday night at the same time the moon will be in
   a) X
   b) Y
   c) Z
   d) V
   e) W

9. Approximately when does a last quarter moon rise?
   a) Sunrise
   b) Midday
   c) Sunset
   d) Midnight
   e) None of the above could be correct.

10. When does a waning crescent set?
   a) Between sunset and midnight
   b) Midnight
   c) Between sunrise and midday
   d) Midday
   e) Between midday and sunset

MOD 172 Heat Transfer
Observing, inferring

OBJECTIVES:

1. Given wire, candle, and tacks, you will demonstrate the conduction of heat through a solid.
2. Given a source of heat and coffee grounds in a pot of water, you will demonstrate the movement of convection currents. Also demonstrate this movement using hot and cold water in two bottles.
3. Given cans, thermometers, styrofoam, and a lamp, you will demonstrate a transfer of heat by radiation.
4. You will formulate a definition of conduction, convection, and radiation.
5. You will apply your knowledge of methods of heat transfer in practical situations given in the questions in this MOD.
6. You will formulate at least one divergent question related to this MOD.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 70 , Formulating Hypotheses II
2. ESS, Heating and Cooling
3. Beckway and Young, Investigations in Earth Science, p. 61
4. Wire, candle, tacks, coffee grounds, glass pyrex pot, bottles, food coloring, cans, thermometers, styrofoam, lamp,

5. The excerpts on heat transfer from physics texts in this MOD. Read Bueche, Principles of Physics, pp. 221, 222, 223.

FINAL ASSESSMENT:

1. Before reporting to the instructor, on the study sheet test your understanding of conduction, convection, and radiation of heat.
2. Ask your instructor for MOD 172 Final Assessment. Correctly complete these 10 multiple choice questions.
3. Discuss with your instructor the questions on pages 2-4 of this MOD.
4. Show your instructor the question that completes objective 6. Be ready to tell why you think it is a divergent question.

PROCEDURE:

1. Conduction

Take a short length of wire from the MOD tray. Attach tacks to the wire by touching the tacks to the wire and dripping melted wax on them. Place three or four tacks about one inch apart. Hold one end of the wire and place the other end in the candle flame. What happens? Infer reasons. Find a theoretical reason for conduction of heat from explanations given in physical science books.

2. Convection

A. Stir four or five teaspoons of used coffee grounds in a clear pyrex container nearly full of water. Place this container on the edge of a hot plate, so that only half the container is over the heat. Observe the system and describe what happens. Why do you think it happens? Sketch a convection current in the space below and be ready to discuss what happens in such a current.

B. Obtain 2 identical small wide-mouthed bottles. Fill one with clear, cold water. Fill the other bottle with hot water and enough food coloring to darken it. Place a stiff piece of cardboard over the bottle of cold water. Hold it firmly, and tip it to place it over the mouth of the other bottle. Slowly remove the cardboard. What happens? Why? Reverse the procedure by placing the cardboard over the hot water, and tipping this bottle over the cold water. Report what happens and suggest reasons.

3. Radiation

A. Put your hand about 12 inches under a lighted bulb. How does the heat reach your hand? Can the process be either conduction or convection? Refer to physical science texts in order to determine if air is a good conductor of heat. The method of heat transfer in this simple activity is the same as that by which heat comes to you from the sun. It is called "radiation" and is the propagation of invisible rays through space.

B. Radiation of both light and heat is either transmitted, absorbed, and/or reflected by objects in the way. If light is absorbed, it is changed into heat. In one hand hold a piece of clear glass several inches from your other hand. Let the light from a lamp shine through the glass to your hand. Does the glass feel warm or cool? How does your hand feel? Describe what is apparently happening.

Take 2 tin cans of equal size. Cover the outside of one with black paper. If the other is shiny, leave it as it is. If it is not, cover it with aluminum foil. Make openings in 2 styrofoam lids for thermometers. Pour enough water into the cans so that the bulbs of the thermometers are submerged in water. Place the lids securely on the cans. Allow the thermometers to reach the same temperature. Then place both cans a short distance away from a lighted lamp. Try to have the light strike the cans only, not the tops of the thermometers. Record below the temperatures of both cans at one-minute intervals for 10 minutes. Turn off the lamp and again record the temperatures at one-minute intervals for 10 minutes. How do you explain the changes observed?

Study Sheet

In preparation for your final assessment, indicate before each statement which method or methods of heat transfer are involved.

A--Conduction B--Convection C--Radiation

_____1. The outside walls of the oven are hot when the oven is on.

_____2. When you walk barefoot, you look for cool places to step so you do not burn your feet.

_____3. The sun warms the earth.

_____4. On a cold day, you touch the radiator and feel its warmth.

_____5. During the winter, when you look above a radiator, you sometimes see "waves" in the air.

_____6. The handle of an iron poker becomes hot when its sharp end is placed in a fire.

_____7. When you eat ice cream, the dish and the spoon feel cool.

_____8. The conditions set up by one method of heat transfer make it an important factor in weather prediction. Which is it?

_____9. Because of the apparent immediate effect of one method of heat transfer, it is often used in heating systems of homes. Which is it?

____10. Your face and hands are warmed as you sit near a campfire.

MOD 173 Peer Teaching of Metric Measurement

PREREQUISITES: MODs 160, 163, 165, and 168

This MOD will allow you to select some measurement activities for children and to refine your understanding of the concepts and ability to teach them with a group of colleagues.

OBJECTIVES:

At the conclusion of this MOD you should have a refined plan for teaching a measurement lesson to elementary children. You should also be able to identify some of your strengths and weaknesses in ability to teach the material using an inquiry approach with recommendations for improvement.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. MMP videocasettes: Measurement I and Measurement II
2. References and materials in SME Resource Center
3. Video recorder and television

INSTRUCTIONS:

1. Select some measurement ideas appropriate for elementary children and develop a 45 minute lesson for teaching the material.
2. Submit, in good form, your plan for review and approval by an instructor. Use the form that you used in MOD 167.
3. With at least three other ISMEP students, teach your lesson to them while videotaping it.
4. Following the taping view the tapes with the ISMEP students and a faculty member and identify weaknesses and strengths.
5. Revise your lesson with the feedback from the review seminar.

FINAL ASSESSMENT:

The MOD will be completed with the submission of a lesson plan revised with feedback from the seminar acceptable to the instructor.

MOD 174 Static Electricity
Observing, inferring

OBJECTIVES:

1. Given an electroscope made of simple materials, you will be able to charge it by contact with either a positive or negative charge and to verify the type of charge.
2. Given the electroscope as in objective 1, you will be able to charge it by induction with either a positive or negative charge and to verify the type of charge.
3. You will demonstrate how to discharge an electrical storage device such as an electroscope or battery by the method of grounding it.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Shipman, Adams, Baker, Wilson, An Introduction to Physical Science
2. Winter, The Physical Sciences
3. Any physical science book on static electricity
4. Stocking, balloons, plastic bag, nylon or fur, 2 strips of nylon, small cork, thread, aluminum foil, wire, jar, plastic ruler, comb

FINAL ASSESSMENT:

Be ready to demonstrate the objectives to the instructor.

PROCEDURE:

Activities demonstrating some effects of static electricity

1. Hold the toe of a stocking against the wall with one hand and with the other hand rub it about 10 times with a dry plastic bag. Remove the stocking from the wall and let it hang freely. The stocking is attracted to nearby objects, but yet it seems to repel itself by "filling up" as if it contained an invisible leg. The following activities help explain the reason for this phenomenon.

2. Blow up 2 balloons and tie them together with a piece of thread or string about 3 feet long. Charge each balloon by rubbing with nylon, fur, or clothing. Hold the middle of the string with your outstretched arm and let the balloons hang freely. Do this several times to determine if the balloons attract or repel each other. Move your hand near one balloon. Is the balloon attracted or repelled to your hand? __________. Bring one balloon near a wall. Is it attracted or repelled? __________.

Lay two strips of nylon on a sheet of paper and rub them firmly with your hand. Lift up the two pieces and place them between your fingers so they are hanging down. Do they attract or repel each other? __________.

Bring each charged piece of nylon near each of the two hanging charged balloons. Do the nylon and balloon attract or repel each other? __________.

A charged object will either attract or repel another charged object. Therefore, there must be two different kinds of charge. Ben Franklin called the two kinds of charges positive and negative (+,-). Arbitrarily call the type of charge on the balloon a negative (-) charge. Since both balloons were charged in the same manner say that both balloons are negative. From what you have seen in activity 1, two negatively charged objects _______(attract or repel) each other.

Both nylon strips were charged in the same way, that is, you rubbed each in the same manner. Therefore, they should __________(attract or repel) each other. Can you decide which charge (+ or -) the nylon had on it? Explain your reasoning below.

Now give your reasoning to account for the "invisible" leg in the stocking.

3. Read Shipman, Adams, Baker, Wilson, An Introduction to Physical Science, pp. 98-102 and Winter, The Physical Sciences, pp. 200-205.

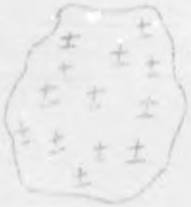
Verify the phenomena stated in the chapter. Instead of a pith ball use a small cork suspended by a thread. Instead of a gold leaf electroscope, use aluminum foil suspended on a wire within a jar. Charge a plastic ruler or pen with the fur contained in the MOD tray. For your final assessment be prepared to demonstrate induction of charge on the electroscope.

4. Charge a comb with fur, nylon or wool and pick up tiny bits of paper. Explain how this occurs. Watch closely. After a moment, one bit of paper shoots off the comb. Then another jumps off. Still more jump off. If they are attracted at first, why are they later repelled? To answer this question examine the following statements and questions.

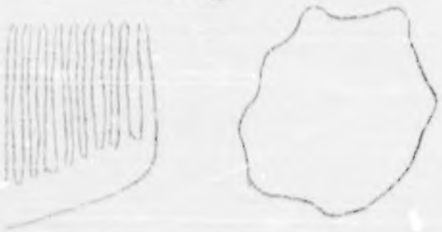
The comb was charged negatively (-).
Were the paper bits charged? ________
What happened to the electrons (negative charge) in the paper when the comb was brought near?
Do they attract or repel each other? ________

Below is a drawing of a bit of paper showing the assemblage of positive and negative charges before the comb was brought near it. Draw in the charges during the time the comb is in the near vicinity of the paper.

Before



During



As soon as the comb touches the bit of paper, a flow of negative charges (electrons) occurs from the ________ to the ________ because ________

____.

Now infer why the bits of paper eventually "shoot" off the comb.

MOD 175 Teaching Metric Measurement

PREREQUISITES: MOD 173

OBJECTIVES:

At the conclusion of this MOD you will be able to describe some difficulties that children have with metric measurement and will be able to identify some of your strengths and weaknesses with teaching selected metric measurements to children.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Lesson plan developed in MOD 173
2. Materials from the SME Resource Center

INSTRUCTIONS:

1. At the scheduled time you will teach the lesson on metric measurement that you developed in MOD 173 to a group of 4 or 5 elementary children using an inquiry approach in an area school.
2. Following the teaching experience you will prepare in writing a list of any difficulties that you encountered along with a list of your strengths and weaknesses with the lesson.

FINAL ASSESSMENT:

1. A seminar to review the teaching experience will be scheduled with an instructor and at least four other ISMEP students. Bring your lists to the evaluation.
2. See objectives.

MOD 176 Bulbs and Batteries I
Predicting, experimenting

OBJECTIVES:

1. Given a small bulb, battery, and wire, you will experiment to see how many ways you can get the bulb to light.
2. Given a bulb, battery, wire, and a box of miscellaneous items, you will test at least six items to see whether they conduct electricity.
3. Given a light bulb, you will take it apart and observe its construction to infer how it should be connected with a battery.
4. Given bulbs, batteries, and wires, you will make predictions on a prepared worksheet and test each system to see how accurate your predictions were.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Bulbs and Batteries, Teacher's Guide
2. #41 bulbs
3. "D" batteries
4. Connecting wires, 15-30 cm long
5. Wire clips, rubber bands, box of junk, triangular file, wire stripper, burned-out household bulb

FINAL ASSESSMENT:

1. See objective 1 and present to the instructor sketches of the arrangements that resulted in a lighted bulb.
2. See objective 2. For the instructor test two objects out of the junk box to see whether they conduct electricity.
3. Be prepared to discuss with the instructor your records of activity 2.
4. Obtain a final assessment sheet from the instructor and fill it out correctly with the instructor and actually test your predictions if necessary.

PROCEDURE:

1. What is necessary to make a bulb light?

A. Try to light a bulb using one battery and one piece of wire. Sketch the arrangement that results in a lighted bulb.

How many other ways can you devise to make the bulb light? Use more wire if you need it. Sketch the successful arrangements in the space below.

B. Try lighting more than one bulb with a single battery. Sketch the successful arrangement.

C. Try lighting one bulb with more than one battery. Sketch the successful arrangement. Suggest alternate ways.

D What particular places on the battery must be touched for the bulb to light?

E. What particular places on the bulb must be touched for it to light? You will understand this better after activity 2C.

F. Try to formulate a generalization about lighting the bulb.

G. Experiment further with the bulbs, batteries, and wires. Then turn to the attached worksheet. Initially make all predictions on the sheet. Then test each system to see whether your prediction is correct.

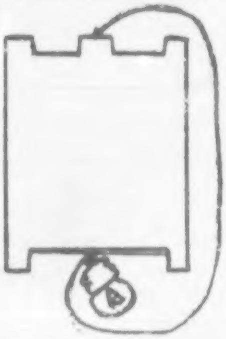
2. How are bulbs made?

A. Look carefully through a magnifying glass at a #41 bulb. Sketch your observation of both the inside and the outside of the bulb.

B. Put an unbroken burned-out household bulb under water in a sink or dishpan. File along the line which divides the glass from the base until water enters the bulb. Record your observation.

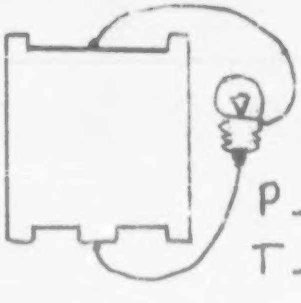
C. If possible, find a burned-out #41 bulb. Remove the base from the bulb by using a wire stripper to twist the silver colored top off the base. Now carefully apply pressure to the base and the glass as if you were breaking a twig. Do this in many positions around the base and soon the glass bulb will be loosened enough to slip out. Inspect the bulb to see why certain places on the bulb must be touched before it will light.

Worksheet:
Predict whether the bulb will light. "Predict" = P____; "Test" = T____



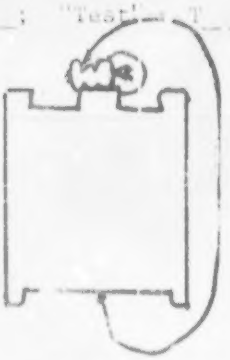
P __

T __



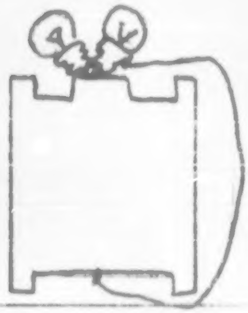
P __

T __



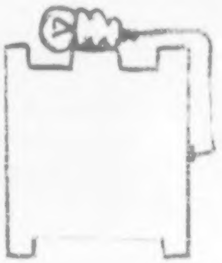
P __

T __



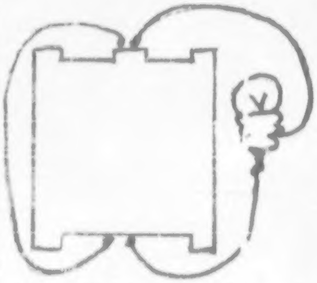
P __

T __



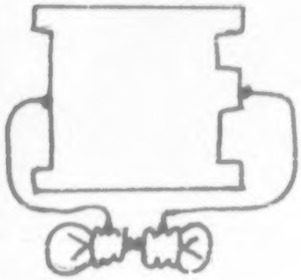
P __

T __



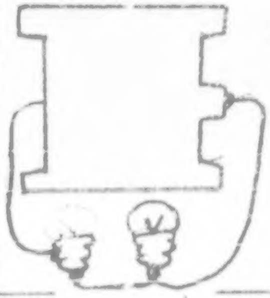
P __

T __



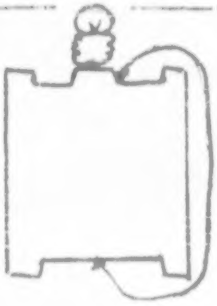
P __

T __



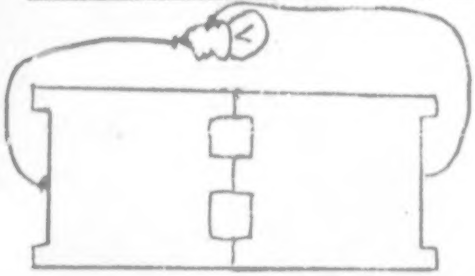
P __

T __



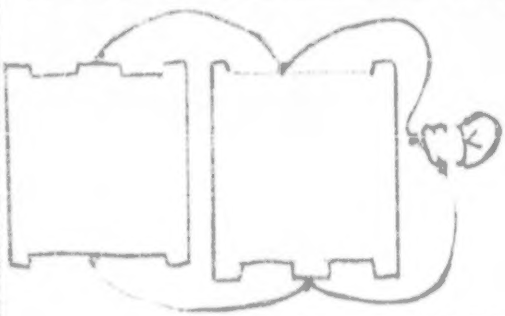
P __

T __



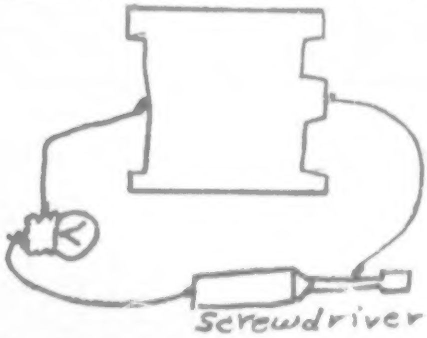
P __

T __



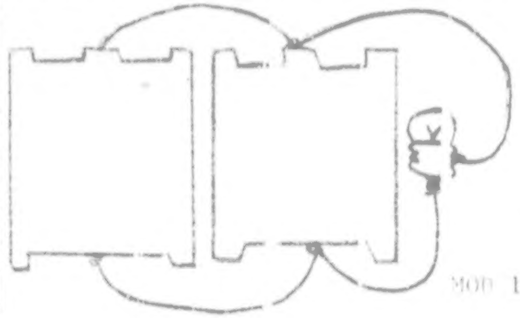
P __

T __


Screwdriver

P __

T __



P __

T __

MOD 177 Optics
Observing, formulating hypotheses

PREREQUISITE: Read Ess, Teacher's Guide for Optics. Be very familiar with this guide; you will refer to it for the activities in this MOD.

OBJECTIVES:

1. You will be able to state a complete hypothesis covering the behavior of light rays, and to give examples of methods used to test the various parts of your hypothesis.
2. You will be able to explain to the instructor the phenomenon of "color."
3. You will be able to give a definition of the following terms that is satisfactory to the instructor: transparent, translucent, opaque, reflection, refraction, luminous, wave length.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Optics, Teacher's Guide
2. Cable, Getchell, Kadesch, and Poppy, The Physical Sciences, Chapter 15, "Illumination"
3. Krauskopf and Beiser, The Physical Universe,
4. ESS, Mirror Cards
5. ESS, Light and Shadows
6. Various masks, shadow sticks, combs, plastic containers, metal mirrors, light source, probe stick

FINAL ASSESSMENT:

1. See objectives above.
2. Bring these activity sheets to your instructor.

PROCEDURE:

Working with light can be interesting and fun. This is useful general information before you begin experimenting.

1. Light occupies a narrow band in the electromagnetic spectrum. Luminous objects or illuminated objects are seen, but light can not be seen unless it is directed toward one's eyes.

2. The intensity of light decreases as the square of the distance from the source.

3. Objects may be transparent, translucent, or opaque. Light striking opaque objects is absorbed or reflected so that the object causes a shadow to be formed.

4. Light striking an object may be reflected, refracted, or absorbed. The angle at which light is reflected from the surface is equal to the angle at which the incident ray strikes the surface. An image in a plane mirror appears to be as far behind the mirror as the object is in front.

5. Light may be refracted as it moves from one transparent material into another, as from air to glass. Lenses change the direction of light rays by refraction, always bending the rays toward the thicker part of the lens.

6. White light is made of light of many colors that can be separated when passed through a prism. The sensation of color depends upon the wavelength of the light energy that reaches the eye. Violet light has high frequency and short wavelength. Red light has low frequency and long wavelength.

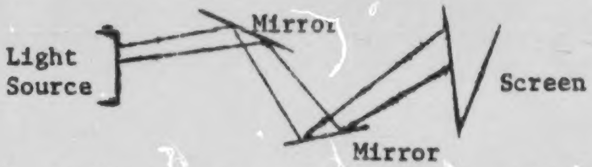
7. The primary colors of light are red, green, and blue. Colors can be mixed by addition, as in overlapping light transmitted through color filters. Primary colors can also be mixed by subtraction. Color by subtraction occurs because some colors are absorbed while others are reflected to the eyes. Colors seen by reflected light are a result of subtraction.

Be very careful while working the activities in this MOD. Follow these safety precautions.

1. Check all wiring for frays. Report damaged wires to the instructor.
2. Check light bulb for broken filament.
3. Work on a scorch-proof surface such as a lab table. The bulb gets very hot.
4. Do not drip water on the hot bulb.
5. If the bulb should break, unplug the light source immediately.

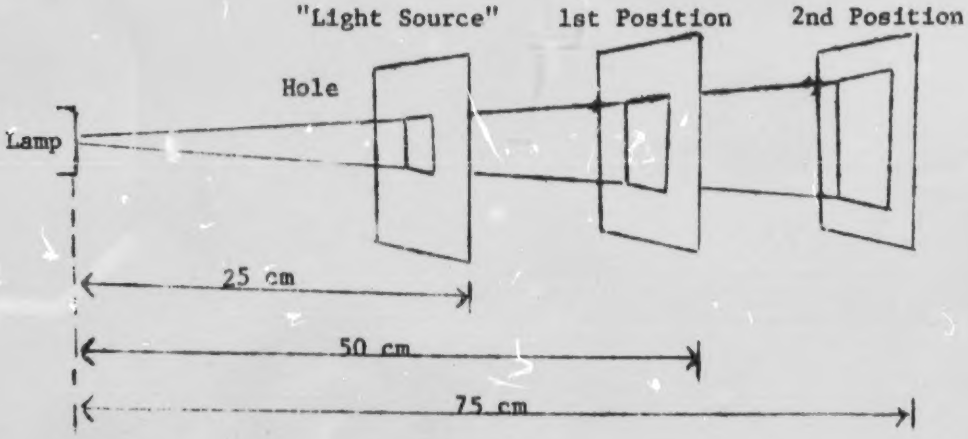
Activities Note: Better observations may be made if you work in a dark or dim area.

1. Mirrors and Light
You will need a light source, metal mirrors, and screen for these activities.



A. Work with your materials. See what you can do to the light with your mirrors. How many times can you reflect the light beam from one mirror to the next, to the next, and so on? What happens to the intensity?

B. Cut a square hole 2 cm. on a side in a piece of stiff paper. Support this piece of paper 25 cm. in front of the lamp. Since the first piece of paper becomes a mask for the lamp, this piece of paper will be referred to as a light source. See the diagram. Support a second piece of stiff paper 50 cm. from the lamp. As carefully as possible draw a line around the illuminated area on the paper in the first position. Measure the illuminated area. Move the paper to the second position 75 cm. from the lamp and repeat the measurement. Does the light intensity decrease? _________ Is the total amount of light energy falling on each total measured surface the same? _________ Make a generalization about the intensity of light.



C. What do you see when you put your wooden probe in front of any mirror?

Place the probe in other positions. Can you see a difference?

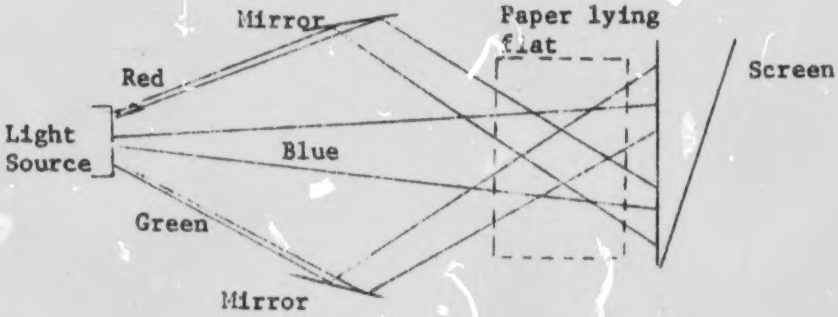
D. Can you place the probe in a position to cast two shadows? _________ four shadows? _________

E. After experimenting, refer to ESS, Optics, Teacher's Guide. Construct a hypothesis using these terms: light rays, reflection, shadows, and intensity.

2. Colored light
The results of this activity are more easily observed in the darkroom. You will need a light source, #3 mask, 2 mirrors, probe stick, and screen. You may want to use a large sheet of white paper lying flat between the light source and your screen. The #3 mask allows 3 narrow beams of colored light to come through.

A. Use your mirrors to reflect the colors across each other. Mix the colors on your screen.

B. How many different colors can you produce by shining the beams together as illustrated in the following diagram?



C. Do an analysis of color mixing in the following table. Name the color you make by mixing the colors.

	Red	Blue	Green
Red			
Blue			
Green			

MOD 177

D. Use your hand as the screen. What do you notice?

Use other non-flat objects as the screen. Does the same effect prevail?

E. Place the probe stick at many different positions. Notice what happens to the shadow. Look very closely.

Can you place the probe stick so that a yellow shadow results? __________ a blue shadow? __________ a red shadow? __________ Is it possible to produce a white shadow? __________ Give your explanation of a shadow and why it can be formed in shades of different colors.

3. Refraction
You will need a light source, mask, plastic container, prism, probe stick, comb, and a screen. Fill your plastic container with tap water. Do not drip water on the hot light bulb.

A. Put a filled container in a beam of white light. What do you observe?

B. Place a pencil in a water-filled container and look at it from the side. Draw what you see.

Can you explain this?

C. Can you produce colors from a white beam? Refer to activity 3A. A prism also refracts light; try using a prism to produce colored light on the screen.

D. Place a probe stick between the light source and the filled container. What happens?

F. Experiment with slit mask #2 and primary color mask #5. Allow each beam to pass through a prism. Do all 3 colors bend the same? ______ Devise an experiment in which you can show how much each color bends. Explain how you set up this experiment and record the sequence of steps.

G. Place a small container inside a larger one. Refer to Optics, Teacher's Guide, p.38. Study the behavior of light through such a system.

H. Add some sugar to the water in the container to see if this affects the bending (length) of the light rays.

I. For a better understanding of color, read ESS, Optics, Teacher's Guide, pp. 45-50.

MODULE 178 MISSING FROM DOCUMENT PRIOR TO ITS BEING SHIPPED TO EDRS FOR FILMING.

BEST COPY AVAILABLE.

MOD 179 Birds in the Environment

PREREQUISITE: Read pp. 8 - 12 in The Land Birds by H. E. Jaques.

OBJECTIVES:

1. Given several bird reference books and binoculars, in the field you will identify at least six different species of birds. If a particular species of bird has a descriptive title prefixing the group name, for example, Scarlet Tanager, Summer Tanager, the full title must be included in the identification.
2. Given a cassette tape recorder, in the field you will record the call of at least three birds excluding the House Sparrow, and identify the birds by comparing their songs to the ones on the reference records in the laboratory.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Jaques, The Land Birds
2. Jaques and Ollivier, The Water Birds
3. Peterson, How to Know the Birds
4. Robbins, Bruun, and Zim, Birds of North America
5. Zim and Gabrielson, Birds
6. Dover Publications, Inc., Common Bird Songs, Booklet and 12-in. record
7. Dover Publications, Inc., Songs of Western Birds, Booklet and 12-in. record
8. Dover Publications, Inc., Songs of Eastern Birds, Booklet and 12-in. record
9. Record player, cassette recorder/player, microphone (Resource Center or AV room)
10. Tape "Bird Songs for MOD 179" (Records & this tape to be obtained from Resource Center)

PROCEDURE:

Follow the steps outlined in the Objectives above. Record the date, time, and location of the sitings and the tapings.

FINAL ASSESSMENT:

1. For objective 1: Bring in a list of six identified birds and the reference(s) that enabled you to identify the birds.
2. For objective 2: Have the cassette recorder and the album ready to play before your appointment time so that the instructor can verify your identification of the bird song.

NOTE: Any equipment used in this MOD is to be signed out for a maximum of 24 hours.

MOD 180 Extended Exercises in Awareness Geometry

OBJECTIVES:

After this MOD you will be able to analyze geometrical shapes in commercial containers, recognize and describe regular polyhedrons, name and identify plane surfaces which can be formed by making plane slices in geometric solids, and demonstrate the use of patterns for discovering relationships in geometric figures.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Awareness Geometry

2. Magnus J. Wenninger, Polyhedral Models in the Classroom, (Reston, Virginia: NCTM, 1966).
3. Potato or modeling clay.
4. Knife or wire with washers on ends.
5. Assortment of solid shapes including several polyhedral shapes.

INSTRUCTIONS:

In the MMP, Awareness Geometry answer on paper or make constructions where applicable for:

Activity 3 - Items 5 (List reasons) and 6
Activity 4 - Items 1, 2, 3 (Cards are in MOD tray), and 4 (Laminate your card game for your permanent file.)
Activity 5 - Items 1, 2, 3, 4, 5, and 6

FINAL ASSESSMENT:

1. Bring paper or constructions to the evaluation.
2. See objectives.
3. Be prepared to discuss your written records and constructions with the instructor.

MODULE 181 MISSING FROM DOCUMENT PRIOR TO ITS BEING SHIPPED TO EDRS FOR FILMING.

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MOD 182 Comparing Volumes

OBJECTIVES:

At the conclusion of this MOD you should be able to:

1. Demonstrate a way to compare two volumes.
2. Identify which of two containers has the larger volume.
3. Demonstrate a way to compare the volumes of two containers by reference to a third container or object.
4. Demonstrate a way to measure the volume of a container using a supplied standard of reference.
5. State and demonstrate the relationship between the volume of a cone and a cylinder with equal bases and heights and between a pyramid and a cube with equal bases and heights.
6. Measure and express in metric units the volumes of containers by using a graduated cylinder.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA 23, Comparing Volumes
2. 15 drinking glasses, of different sizes, labeled A-O
3. Masking tape
4. Felt-marking pen
5. Containers, several 30 ml.
6. Sand
7. Paper for recording data
8. Two fairly large boxes about the same size, labeled A and B
9. Geometric containers, plastic: cone, cylinder, pyramid, cube
10. Graduated cylinders

INSTRUCTIONS:

1. In SAPA 23 Comparing Volumes read "Rationale" and "Introduction" pp. 3-4.
2. Perform Activity 1(Be sure to record your data).
3. Bring five rectangular boxes of your choice and perform Activity 2.
4. Using boxes A and B perform Activity 3.
5. Using a graduated cylinder measure and record the volumes of the glasses and the geometric containers in Activity 1.
6. State a relationship between the volume of the cone and cylinder and the cube and pyramid.

FINAL ASSESSMENT:

1. Bring all data to the assessment.
2. See objectives.

MOD 183 Properties of Lenses and Mirrors
Observing, defining operationally

PREREQUISITES: MOD 177, "Optics"

OBJECTIVES:

1. Given a light bulb, concave mirror, tape measure, and paper, you will be able to bring an image of the light bulb to focus by using the concave mirror.
2. Given the materials in objective 1, you will be able to manipulate the light, mirror, and paper screen to show a relationship between the following variables:
   a. image size
   b. object distance (i.e., distance between light and wall)
3. Given a convex lens, light, tape measure, and paper screen, you will be able to perform the same investigation as for objective 2 except that the word "lens" will be substituted in place of "mirror."
4. Given two convex lenses of different focal lengths, you will be able to manipulate them to make a simple microscope and telescope.
5. Given a concave mirror and a convex lens, you will be able to manipulate them to make a simple telescope.
6. You will be able to determine the focal length of a concave mirror or convex lens.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Physical science books on lenses and mirrors
2. Light bulb, concave mirror, tape measure, convex lens, paper screen

FINAL ASSESSMENT:

1. See objectives above.
2. You will be asked to demonstrate for your instructor your ability to manipulate a concave mirror and/or convex lens in order to find its focal length.

PROCEDURE:

General Information

If you are a learner who likes to read background information on the subject before investigating on your own, use the physical science texts found in the ISMEP resource center. By reading you might "discover" relationships from the text information that otherwise would go unnoticed in actual investigation. However, the process objectives for this MOD are observing and defining operationally and these skills, of course, can not be obtained by textbook knowledge. Therefore, it will be necessary for you to gather data using some of the materials in the MOD tray.

Activities

1. Obtain an image of the light by placing the light bulb between the mirror and the screen (or wall) and moving the mirror back and forth. As you probably notice, the mirror will project a somewhat dim image at one location. By keeping the light in the same place but moving the mirror a greater distance from the light, a brighter image will be formed. This is because the mirror has two surfaces which are reflecting, the front concave surface (dim reflection) and the silvered "rear" surface (brighter reflection). Use the brighter image for your investigations.

2. Place a light bulb that is lighted on a chalk mark on the floor. Measure the distance from the light to the wall. Move the concave mirror in and out until an image is formed on the wall. Is the image inverted, or is it right side up? ____________ Measure the size of the image, and the distance between the light and the wall. Also measure the distance between the mirror and the object when the image is in focus. Call this trial #1 and record your data for this and all your repeated trials. Repeat the steps above but change the distance between the light and the wall. With the mirror again bring the image to focus on the wall. Record the data for your trials below.

	Wall-Light Distance	Image Size	Mirror-Object Distance
Trial #1			
Trial #2			
Trial #3			
Trial #4			
Trial #5			

Looking at your data complete the relationship statement below.

As the wall-light distance ___________(increases or decreases) the image size ___________(increases or decreases). Is this an inverse or direct proportion? _____________

In all 5 trials is the distance between the mirror and the light approximately the same or is the distance markedly different? The distance is to be observed when the image is in focus.

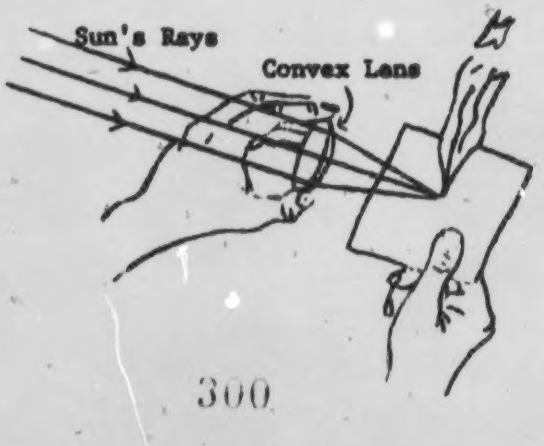
Place the light on a chalk mark on the floor and measure the distance from the light to the wall. Manipulate the lens to get a sharp image of the light source on the wall. Is the image inverted or is it right side up? ___________ Measure the size of the image and the distance between the light and wall. Call this trial #6 and record your data below. Also observe the distance between the lens and the light when the image is in focus. Repeat for trials 7, 8, 9, 10 by varying the object-wall distance.

	Wall-Light Distance	Image Size	Lens-Light Distance (when image is in focus)
Trial #6			
Trial #7			
Trial #8			
Trial #9			
Trial #10			

Examine your data and complete the following relationship statements:

As the wall-light distance ___________(increases or decreases) the image size ___________(increases or decreases). As the wall-light distance __________ (increases or decreases) the distance when image is in focus between the lens and light ___________(increases or decreases).

4. The focal length of a convex lens can be roughly defined as the distance between the center of the lens and the smallest dot obtained on a screen when parallel rays (e.g. from the sun) pass through the lens. See the diagram below.



Simple Telescope

The 'power" of a telescope is obtained by the objective lens (lens farthest from eye) focal length divided by the focal length of the eyepiece (lens closest to the eye).

Find the focal lengths of two lenses in the box by using the sun as a light source. Record these focal lengths. Next, hold a lens in each hand and manipulate them to get an outdoor scene to appear larger.

Simple Microscope

Using the same two lenses as in the simple telescope, manipulate the lenses so an object can be magnified as in a microscope. Hold the lens with the longer focal length next to your eye.

5. With your back to the window hold the concave mirror at arm's length. Looking at the mirror, you will observe a blurred scene. Next try to bring the blurred outdoor scene into focus by observing the mirror through a convex lens. Hold the lens next to your eye. You might need an assistant to hold the mirror for you in order to get enough distance between the eyepiece and mirror for proper focus.

To obtain the magnifying power of this simple telescope you need to know the focal lengths of both the mirror and lens. Since you probably already know the focal length of the lens from the previous activity, you will only have to obtain the mirror's focal length. Let direct sunlight hit the mirror and reflect to a dark paper or cardboard surface. When you get a small dot and eventually smoke, measure the distance from the center of the mirror and the dark paper screen. This distance is the focal length of the mirror. Be very careful not to look at the direct rays of the sun in the mirror. You may be blinded!

Divide the focal length of the mirror by the focal length of the eyepiece. The answer is the magnifying power of this reflecting telescope system.

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MOD 185 Extending Metric Measures

This MOD is planned to provide you with drill to strengthen your metric measurement knowledge and personal confidence in using metric measurement. Since we are rapidly moving into the metric system of measurement, it is important that this be stressed in our integrated science-mathematics-education program for the preservice elementary teacher.

OBJECTIVES:

The student will:
1. Be able to handle the prefixes with confidence
2. Be able to think metric
3. Be able to compute in metric measurement

MATERIALS:

Work sheets 1 - 12, found in drawer in desk at front of lab
Assorted metrics reference books found in Resource Center like booklet "What about Metric?"

INSTRUCTIONS:

Complete all twelve sheets alone in so far as possible. Consult with partner and reference materials as needed.

FINAL ASSESSMENT:

1. Leave the completed exercise sheets with the secretary. After the sheets have been reviewed, they will be returned in your box.
2. If your sheets are checked as acceptable, ask the secretary for a 10-item paper-and-pencil quiz and complete it (to be done individually without references).
3. Successful completion of the MOD will be determined by successfully completing the exercise sheets and obtaining 80% competency on the paper-and-pencil quiz.

MOD 185

MOST FREQUENTLY USED METRIC UNITS

Attribute	Unit	Symbol
Length	kilometer	km
	meter	m
	centimeter	cm
	millimeter	mm
Area	square kilometer	km^2
	hectare (10,000 m^2)	ha
	square meter	m^2
	square centimeter	cm^2
Volume or Capacity	cubic meter	m^3
	cubic decimeter	dm^3
	liter	L
	cubic centimeter	cm^3
	milliliter	mL
Mass (weight)	metric ton (1000 kg)	t
	kilogram	kg
	gram	g
	milligram	mg
Time	day	d
	hour	h
	minute	min
	second	s
Temperature	degree Celsius	°C
Speed or Velocity	meter per second	m/s
	kilometer per hour	km/h
Plane Angle	degree	°

MOD 186 Identification of Gases
Defining Operationally

OBJECTIVES:

1. Given a pan of water, tubing, and a jar, you will collect over water the air you exhale.
2. Given vinegar and baking soda, you will generate and collect carbon dioxide gas (CO_2) and test it for its properties.
3. Given hydrogen peroxide and manganese dioxide, you will generate and collect oxygen gas and test it for its properties.
4. Given iron filings in a plastic bag, you will obtain nitrogen gas and test it for its properties.
5. Given activities 2, 3, and 4 above, you will formulate operational definitions for carbon dioxide, oxygen, and nitrogen.
6. You will collect gas evolved from a seltzer tablet by any workable means which you devise and identify the gas by carrying out appropriate tests.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 92, Three Gases.
2. Pans, gallon jar, tubing, pint jars, vinegar, baking soda, limewater, bromothymol blue solution, manganese dioxide, 3% hydrogen peroxide, iron filings, plastic bags, sealing wax, seltzer tablets

FINAL ASSESSMENT:

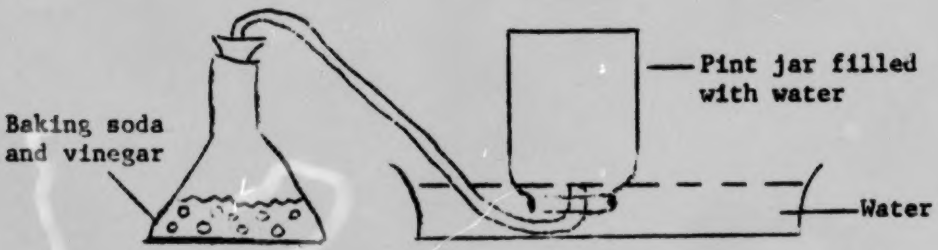
1. Report your work for objectives 1, 2, 3, and 4 to the instructor.
2. See objective 5.
3. Report of results pertaining to objective 6 above.

PROCEDURE:

Work in groups of 3 or 4 if possible. Read directions carefully before you begin to work.

1. Invert a gallon jar filled with water, and place it in a pan of water so that the open end is under water. Take a deep breath and exhale through a tube that leads to the open mouth of the gallon jar. See how much of your exhaled air you can collect over water. This procedure which shows you the general technique for collecting gases over water will be useful in the following activities.

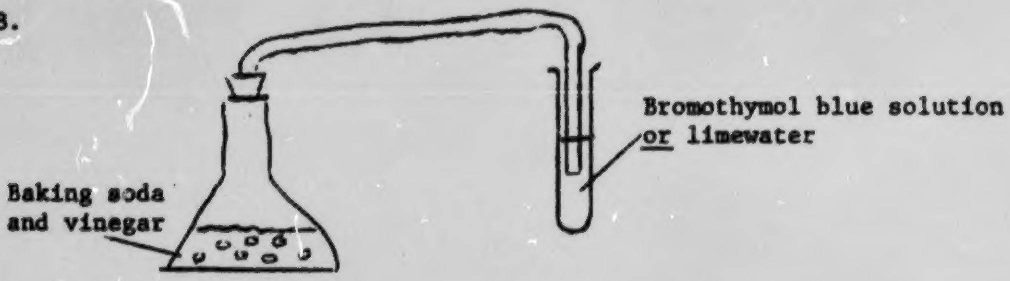
2. A.



Put about 20 g. of baking soda in a 250 ml. flask and measure out in a separate container about 47 ml. of white vinegar. Do not mix the vinegar and baking soda until all of the equipment is ready and the collecting jar is filled with water and ready to be inverted over the tubing. Use a pint jar. Hold on to the jar in the water.

When the equipment is ready, add the vinegar to the baking soda and put the cork with the tubing inserted into the flask. When the jar is filled with carbon dioxide, lift up the jar carefully and quickly put plate glass over the mouth of the jar. Try burning a match in the jar. "Pour out" the remaining contents of the jar on to a burning candle. Record below what happens.

2. B.



Mix 15 g. of baking soda and 35 ml. of white vinegar and lead the carbon dioxide that evolves through a tube so that it bubbles through a test tube half full of bromothymol blue solution and a test tube half full of limewater. Record below what happens.

In the space below, write an operational definition of carbon dioxide based on what you observed in A and B above.

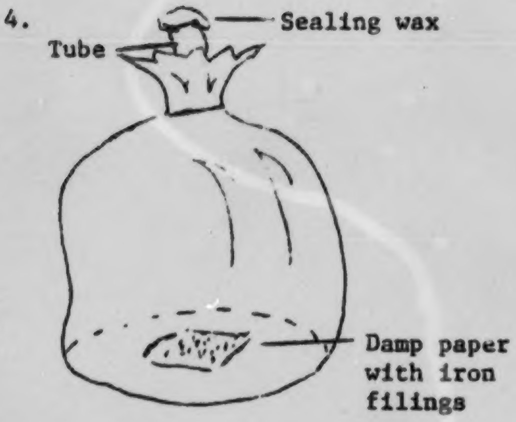
3. Use the same kind of apparatus as in 2 above. Be sure the flask is clean.

A. Add ½ tsp. of manganese dioxide to 100 ml. of hydrogen perioxide (3% solution in water) and collect the oxygen that evolves in a pint jar over water. Light a wood splint, allow it to burn for a time, blow it out, and insert a glowing splint into the jar. Record below what happens. Invert the jar over a burning birthday candle. Results?

B. Add ½ tsp. of manganese dioxide to 50 ml. of hydrogen peroxide and allow the oxygen that evolves to bubble through a test tube half full of bromothymol blue solution and another test tube half full of limewater. Record the results.

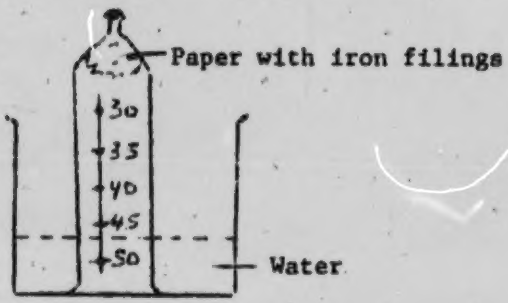
Write an operational definition of oxygen based on what you observed in 3, A and B.

4.



A. Cut a piece of paper towel about 4 cm. by 4 cm. and dip it in water. Sprinkle iron filings on it until the surface is just covered. Fold the piece of paper towel in half so that the filings are inside. Put the paper and iron filings inside a plastic bag that has a pint capacity. With a rubber band, close the bag tightly around a in. length of stiff plastic or glass tubing and seal the end of the tube with sealing wax or modeling clay as shown in the diagram. Set the bag aside for 24 hours.

B. Cut and moisten another piece of paper towel sprinkled with iron filings. Roll it and insert it into the barrel of a 50 cc. syringe. Force it into the tip of the barrel so that it will not fall out when the barrel is inverted. Put enough water in a beaker so that the water level in the syringe will be between the marks for 45 and 50 cc. when the syringe is placed into the beaker. See the diagram. After the syringe is in the water, seal the top with sealing wax or modeling clay. Set it aside for 24 hours. After 24 hours, read the water level inside the syringe and calculate how much of the original air was nitrogen. Assume that what remains in the syringe is mostly nitrogen and that the oxygen was used up in combining with the iron filings.



After 24 hrs. return to the plastic bag prepared in activity 4A which should then contain mostly nitrogen. Quickly remove the seal and attach a length of flexible tubing. Then squeeze out some of the nitrogen so that it bubbles through a test tube half full of bromothymol blue solution and another test tube half full of limewater. Record the results below.

Squeeze some nitrogen into a test tube or use the nitrogen remaining in the syringe prepared in activity 4B. Thrust a burning match into the nitrogen gas. Record the results below.

In the space below, write an operational definition of nitrogen based on what you observed in the activities outlined above.

5. In the space below, describe the method and arguments you used in order to achieve objective 6.

MOD 187 Respiration
Experimenting, hypothesizing

OBJECTIVES:

1. From the observations made in your experiments, you will be able to show that plants in their metabolism produce carbon dioxide.
2. From the observations made in your experiments, you will be able to show that plants in their metabolism use and produce oxygen.
3. From the information gained in this MOD, you will be able to convince the instructor that plants in respiration use an amount of oxygen equal to the amount of carbon dioxide they produce.

Optional

4. You will design an experiment in which you could show the instructor that plants use carbon dioxide in their metabolism.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 92, Three Gases
2. This MOD, pp. 2-5
3. General biology and botany references
4. Drinking straws, bromothymol blue, test tubes, funnel, Elodea, beaker (400 ml), sodium bicarbonate solution, potassium hydroxide solution, ring stand, clamp
5. SCIS, Ecosystems, Teacher's Guide, pp. 59-76

FINAL ASSESSMENT:

1. See objectives 1-3 above.
2. Report on your design, if you completed objective 4.

PROCEDURE:

Metabolism

This MOD is called "Respiration" although this general information is about metabolism. It and other related terminology need to be clarified.

External Respiration: The exchange of gases between the environment outside the organism and the organism. This exchange takes place across the linings inside the lungs. Note that the space inside the lungs is actually a part of the external environment in that it is continuous (open) to the air outside.

Internal Respiration: The exchange of gases between the blood (or space around the cells) and the cells.

Metabolism: The total of all chemical reactions that take place in a living organism.

Respiration: Those chemical reactions in a living organism that use oxygen and produce carbon dioxide.

All living organisms must metabolize in order to carry on life-sustaining processes, such as growth, reproduction, repair, and motion. Organisms must constantly build large chemical substances from smaller ones (anabolism) and must constantly tear down large molecules in repair and to use substances for energy (catabolism). One example of a catabolic reaction is breaking down fuel substances to realize the energy stored in these substances. With the exception of a few bacteria, most organisms use oxygen and produce carbon dioxide in these particular catabolic reactions. These reactions are examples of respiration. All green plants are capable of building large chemical substances from the basic raw materials, as carbon dioxide and water, in a process called photosynthesis. Photosynthesis is one example of an anabolic process. A living organism carries on many anabolic and catabolic reactions. Respiration and photosynthesis are but two examples.

Reflect on the use and production of oxygen and carbon dioxide to realize that we must have a balanced system. Living organisms must produce as much oxygen as they use if the oxygen content of the air is to remain the same. Likewise living organisms must produce as much carbon dioxide as they use. If this were not the case then one or the other would soon be depleted from the air. How is this balance maintained?

Consider what happens to all the carbon dioxide produced. Where does all the oxygen come from? Look at some generalized chemical reactions representative of the respiration and photosynthetic mechanisms.

$$\underset{\text{(oxygen)}}{6\ O_2} + \underset{\text{(glucose or sugar)}}{C_6H_{12}O_6} \longrightarrow \underset{\text{(carbon dioxide)}}{6\ CO_2} + \underset{\text{(water)}}{6\ H_2O} + \text{chemical energy}$$

This reaction is a generalization of a number of reactions resulting in the breakdown of fuel (glucose, sugar, starch or glycogen), requiring the use of oxygen, and producing water, carbon dioxide, and chemical energy. These reactions make up the process of respiration. Note that the reaction above uses and produces approximately equal quantities of oxygen and carbon dioxide, respectively. Where does the water come from?

$$\underset{\text{(water)}}{6\ H_2O} + \underset{\text{(carbon dioxide)}}{6\ CO_2} \xrightarrow{\text{(Energy)}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\ O_2}$$

This is a generalization of a sequence of chemical reactions using water and carbon dioxide and producing glucose, sugars, or starch and oxygen. These chemical reactions are collectively called "photosynthesis" and are produced by green plants. Photosynthetic reactions are an example of anabolic reactions as respiration is an example of catabolic reaction. Note that in the above reaction carbon dioxide is used in amounts relative to the oxygen produced. In nature there is a balance between the amount of oxygen that is needed for respiration by plants and animals and the amount that is produced in photosynthesis. There is also a balance between the amount of carbon dioxide that is produced by plant and animal respiration and the amount that is used by plants in photosynthesis.

Information necessary to properly analyze your results:

1. Carbon dioxide is very soluble in water that contains potassium hydroxide. If carbon dioxide is produced in a container that has some potassium hydroxide and water in it, the carbon dioxide will be absorbed and the air volume will not change because of the carbon dioxide production.

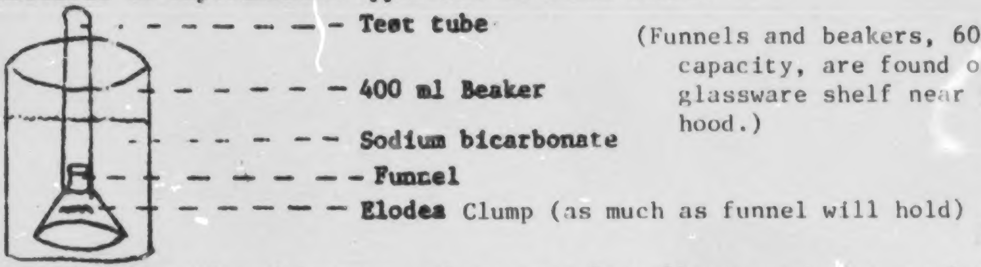
2. If air containing carbon dioxide is bubbled through a solution of bromothymol blue, the solution will lose its blue color.

3. A glowing splinter of wood, placed in a tube containing oxygen, will glow brighter or burst into a flame.

Activities:

1. Place about 2 cm. of a bromothymol blue solution in a test tube. With a straw, blow air from the lungs through the tube. Does the color change? __________ What substance caused the changes?

2. Assemble an experimental apparatus as shown below.


Test tube
400 ml Beaker
Sodium bicarbonate
Funnel
Elodea Clump (as much as funnel will hold)

(Funnels and beakers, 600 ml capacity, are found on the glassware shelf near the hood.)

A. Fill the tube with water, place your fore-finger over the opening, invert and submerge it in the sodium bicarbonate and place it over the funnel tube. Support the test tube with a ring stand and clamp.

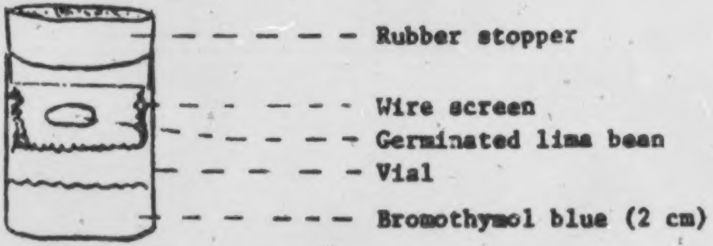
B. Place the set-up under a fluorscent light and leave for several hours or overnight.

C. When the tube has been filled to at least 3/4 full of gas by displacement of the water, remove the tube by again placing your fore-finger over the opening.

D. Light a wood splinter and allow it to burn for a few seconds. Blow out the flame and insert the glowing splinter into the tube. Some water in the bottom of the tube will not interfere with the test.

E. What gas had collected in the tube? _______________ What was the process that produced it?

3. Obtain a germinated lima bean seed from the supply tray. Place it in an apparatus as shown below.

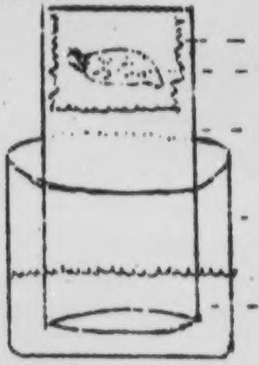

Rubber stopper
Wire screen
Germinated lima bean
Vial
Bromothymol blue (2 cm)

A. Allow the preparation to stand overnight in the dark by placing it in the cabinet at the back of the room.

B. What changes do you see?

C. Did this plant carry on respiration only or did it also carry on photosynthesis?

4. Obtain a germinated lima bean seed from the supply tray and place it in the apparatus as shown below. When you place the vial in the beaker, try to keep equal the levels of potassium hydroxide-water solution in the vial and in the beaker.


Wire screen support
Germinated lima bean
Inverted vial
50 ml beaker
Potassium hydroxide-water solution

A. Place the apparatus in a dark cabinet overnight at the back of the room.

B. What changes do you observe in the water level in the beaker? What changes do you observe in the vial?

C. What gas that was produced was absorbed by the potassium hydroxide?

D. What gas was used by the seed?

5. Repeat activity 4, but this time use distilled water in place of the potassium hydroxide-water solution. Why would you expect the water level to remain unchanged?

MOD 188 Pattern Blocks

If possible pursue this MOD with one or two other ISMEP teams.

OBJECTIVES:

Given a set of Pattern Blocks, you will:

1. Name the shapes and arrange blocks into subsets based on different properties.
2. Construct similar figures when given pictures or other designs from Pattern Blocks.
3. Construct and analyze larger shapes made from a given small shape.
4. Construct one shape out of other shapes.
5. Design and fill in Pattern Block puzzles
6. Construct designs with Pattern Blocks and mirrors.
7. Determine perimeters and areas of the shapes or designs constructed with Pattern Blocks.
8. Construct figures with specified areas and perimeters.
9. Construct and identify polygons with 7, 8, 9, 10, 11, and 12 sides and convex, equilateral, and equiangular polygons.
10. Construct at least 8 Pattern Block puzzles on heavy paper.
11. Demonstrate and explain mirror symmetry, symmetry of rotation and symmetry of translation with Pattern Block designs.
12. Identify fractional parts of figures constructed from Pattern Blocks.
13. Demonstrate addition and subtraction problems, multiplication facts, squared numbers and number sequences, and addition and subtraction of fractions.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. ESS, Teacher's Guide for Pattern Blocks
2. Bag of Pattern Blocks
3. Three Mirrors
4. Heavy paper

INSTRUCTIONS:

Read Teacher's Guide for Pattern Blocks and do the suggested activities that interest you. You may wish to design some of your own. Be sure to do some activities that contribute to the outlined objectives.

FINAL ASSESSMENT:

1. Bring puzzles prepared for objective 10.
2. See objectives.

MOD 189 **Electricity and Chemistry**
Inferring, formulating hypotheses

PREREQUISITES: Completion of MOD 174, "Static Electricity;" MOD 176, "Batteries and Bulbs I."

OBJECTIVES:

1. Given the materials listed below and having performed the enclosed tasks, you will state and test a hypothesis concerning the conductivity of certain chemical solutions.
2. Given lemon juice, wires and a voltmeter, you will make and demonstrate an electrical cell.
3. Given blotter paper, an acid-base indicator (BTB), saltwater batteries, and wires, you will demonstrate the effects of an electrical current on acids and bases.

INSTRUCTIONAL REFERENCES & MATERIALS:

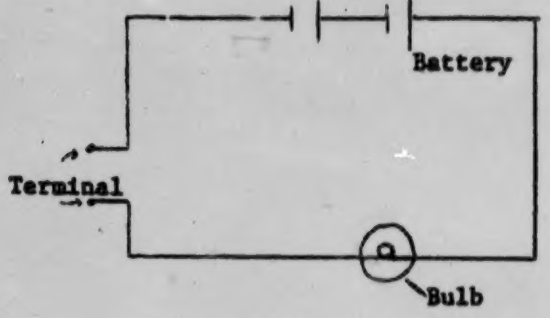
1. Karplus, Introductory Physics
2. SCIS, Models: Electric and Magnetic Interactions, Teacher's Guide
3. 2 cells (1.5 v), connecting wires, brass clips, BTB concentrate, salt, paper towels, lemon juice, #48 light bulb, voltmeter, beaker

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

1. Prepare a 2-battery, switch, and bulb series circuit as diagramed.



2. Place the two terminals into a small beaker of common salt. Is there any evidence of a completed circuit through the salt? __________ Make an inference regarding this observation.

3. Place the two terminals into a small clean beaker of tap water. Is there any evidence of a completed circuit through the tap water? _________ Make an inference regarding this observation.

4. Mix the salt and water and wait for the remaining salt to settle to the bottom of the container. Now, place the terminals into the saltwater solution to test for conductivity of salt water. Formulate a hypothesis that would explain your observations.

A. Collect additional data to test your hypothesis. Use the back of this paper for more data if necessary.

B. Which of your additional data supports your hypothesis?

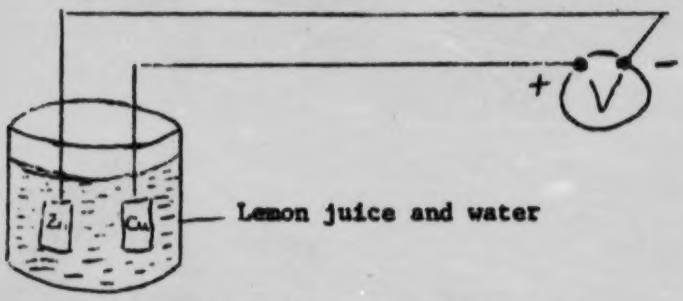
C. Which of your additional data would tend to weaken you hypothesis?

NOTE: Save your salt water for activity 3 of this MOD.

2. A. Prepare a solution of concentrated lemon juice and water in any proportion and record your data below:

1 part lemon juice to ________ parts water

B. You will find a zinc and a copper plated attached to the wires located in the MOD tray. Connect the wires to a voltmeter as follows:



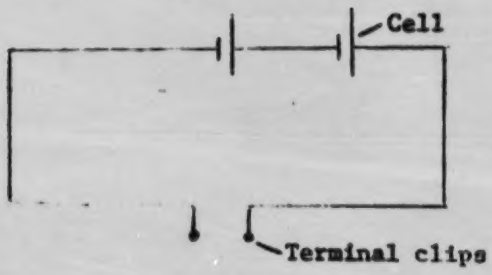
C. Does the voltmeter show a current flow? __________ Try different proportions of lemon juice and water to see if you can increase the voltage.

Proportion: 1 to _________; voltage = _________

1 to _________; voltage = _________

D. Read Karplus, Introductory Physics, pp. 317-320 and UNESCO, Sourcebook for Science Teaching, p. 168, "Simple Electric Cells," Topics 1-13.

3. A. For the following activity you will need these materials: salt water solution, bromothymol blue (BTB), white paper towel or blotter, and the following battery circuit:



B. Bromothymol blue is an acid indicator that turns from blue to yellow in the presence of an acid. Refer to SCIS, Teacher's Guide for Models, p. 109 and carry out the experiment in the second paragraph of that page. Record the results of this experiment and any other observations you make below.

C. State a hypothesis giving the cause of the reaction using the terms electron, metal clips, salt water, and hydrogen.

MODULE 190 MISSING FROM DOCUMENT PRIOR TO ITS BEING
SHIPPED TO EDRS FOR FILMING.

BEST COPY AVAILABLE.

MOD 191 Match and Measure

"Match and MEasure" is designed to help you identify measurement problems appropriate for elementary children and to give you additional experiences with metric measurement. In order to "think metric" many predictions and measurements should be made in the metric system.

OBJECTIVES:

At the end of this MOD you will be able to

1. Discuss some appropriate measurement activities for children
2. Select the appropriate metric unit of measure for various objects
3. Predict and measure linear dimensions, mass and volume of select objects
4. Predict change in volume as a result of doubling and tripling the dimensions of an object
5. Use a micrometer for making small linear measurements
6. State whether there is a relationship between the perimeter and area of an object
7. State the relationship between the mass and volume (capacity) of water

INSTRUCTIONAL MATERIALS & EQUIPMENT:

1. Teacher's Guide for Match and Measure
2. Duplicated sheet from Duplicator Master 5
3. Task Cards 1, 10, 26, 30, 38, 46, 48, 49, and 54
4. String, 2 paper cups, cardboard, construction paper, playing card
5. 30cm measuring stick, balance, graduated cylinder, quart jar
6. Popcorn, beans
7. Hot plate, sauce pan with cover
8. Cup, measuring cup, teaspoon, tablespoon
9. Micrometer
10. Scissors, masking tape, centimeter grid paper

INSTRUCTIONS:

1. Read and discuss the activities suggested in the Teacher's Guide for Match and Measure.
2. Obtain from the next page a duplicated sheet from Duplicator Master 5 and complete the activities.
3. Perform the activities from Task Cards 1, 10, 26, 30, 38, 46, 48, 49, and 54, and keep all records.

FINAL ASSESSMENT:

1. Bring all records to the assessment.
2. Be prepared to discuss the activities and your records.

MOD 191

Duplicator Master 5

Name ______________________________ Date ____________________

HOW LONG IS THE STRING?

Teacher's Note: If a metric ruler is used, have children measure the parts of their bodies using string and then have them measure the string to determine body measurements. Discuss with the students the need for standard units when communicating with each other.

PROBLEM: Estimate lengths using string, then verify your measurements

MATERIALS: String, meter stick or centimeter cubes.

DIRECTIONS

1. Decide on an appropriate unit of measure.
2. Estimate and then measure each of the following using a piece of string, then measure the string.

		guess	measured
a.	hand span (fingers spread wide apart)	________	________
b.	reach (both arms outstretched)	________	________
[illegible]	height	________	________
d.	width of little finger	________	________
e.	length of your little finger	________	________
f.	distance around your fist	________	________
g.	distance around your waist	________	________
h.	distance around your wrist	________	________
i.	distance around your thumb	________	________
j.	length of your math book	________	________
k.	distance around the handle of a baseball bat	________	________
l.	distance around a door knob	________	________
m.	circumference of neck	________	________
n.	length from elbow to end of longest finger	________	________
o.	length from nose to end of outstretched hand	________	________

EXTENSIONS: Have students compare measures to determine ratio, e.g., circumference of waist to circumference of neck.

[illegible] body measurements. Then have them

MOD 192 Kinetic-Molecular Theory of Matter
Inferring

OBJECTIVES:

1. Given the demonstrations described on the following pages, and given the kinetic-molecular theory as a basic premise, you will infer what is happening in molecular terms in each demonstration.
2. You will give 3 examples of practical application of the kinetic-molecular theory in your everyday world - excluding the ones in this MOD.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. UNESCO, Source Book for Science Teaching
2. Units on kinetic-molecular theory from any college physical science textbook
3. Knipp tube, candles, hot plate, medicine droppers, ink, ammonia, long metal wire, weight, glass tube, hydrochloric acid, plate, balloon, bottles
4. Ealing Film-Loop, Motion of a Molecule, filmloop #80-3351
5. Ealing Film-Loop, Random Walk and Brownian Motion, filmloop #80-2926/1
6. 8 mm. filmloop projector

FINAL ASSESSMENT:

1. Present to the instructor your written inferences on the following pages and be prepared to discuss and defend them.
2. Report your list of applications to the instructor.
3. Read gas laws and work inserted problems on p. 152 of Astronomy by Bash, 1977. Harper & Row.

PROCEDURE:

The basic assumptions of the general kinetic-molecular theory are:

1) All material things are made up of tiny particles called molecules.
2) Molecules are in constant motion.
3) The distances of separation of the molecules are great, relative to the size of the molecule.
4) When colliding with each other and/or the walls of the container, the molecules rebound with perfect elasticity.

Note: As kinetic energy (the energy of motion) = $\frac{1}{2}mv^2$, then the velocity of the molecules will be proportional to the kinetic energy (Ek) they contain. This will in turn be proportional to the temperature of the gas.

In any college physical science text, study the sections dealing with kinetic-molecular theory and its implications in heat phenomena, particularly in changes of state. Then perform the following demonstrations and formulate your inferences.

1. Place a bottle of ammonium hydroxide at one end of the laboratory and place three people at intervals in a line across the room so that the first person is about 6 ft. from the bottle. Take the stopper out of the bottle and ask the persons to tell you when they begin to smell ammonia. What inferences can you make about why the persons smelled the ammonia, and how it reached them? Refer to the assumption in the Kinetic theory. Oil of cloves will be as effective in such a demonstration for children.

2. Put a level teaspoon of salt into a glass full of tap water and stir. After stirring, can you see any salt? Use a clean medicine dropper and get samples of water from the surface and at different levels in the glass. Taste these samples. Infer from the kinetic-molecular theory what has happened to the salt.

3. Take a long, clear glass tube, and in one end place a wad of cotton soaked in hydrochloric acid. In the other end place a similar wad soaked in ammonium hydroxide. Observe carefully, describe what you see, and infer what has happened to the molecules in the system. You may wish to consult some of your friends in chemistry.

4. A. View the following filmloops: Motion of a Molecule, Random Walk and Brownian Motion

B. Observe what you see when you clap together two "chalky" blackboard erasers in a beam of sunlight. What can you infer from the kinetic-molecular theory to explain what you see?

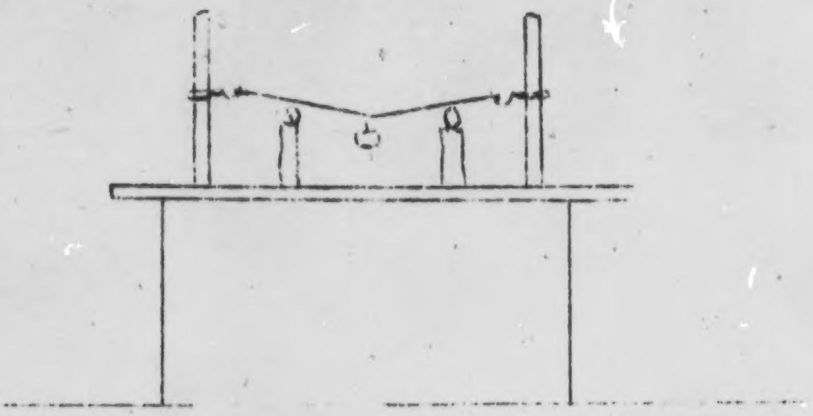
C. Caution: Handle the tube carefully and do not let it roll off the table! Heat the Knipp tube with the mercury and blue glass pieces in it over a candle. Rotate it slowly so that the tube is heated evenly. After a short time, you will observe unusual activity inside the tube. Describe what you see, and infer from the kinetic-molecular theory what is happening.

5. A. Obtain a cupful of crushed ice and observe it as it melts. What can you infer about the behavior of the molecules in this physical change?

B. Using a hot plate, boil the water resulting from melting the ice. What you see is a change of state. From the kinetic-molecular theory infer an explanation of what you observe.

C. As the water boils in the demonstration above hold a plate in the "cloud" that is formed and observe what happens. Use the kinetic-molecular theory to explain what you see.

6. A.



From the clamps attached to two vertical poles in the table, fasten a length of wire. Hang a weight from the middle of the wire. Measure the distance between the weight and the table. Then heat the wire with some candles and observe what happens to the distance from the weight to the table. Why does this happen? Use the kinetic-molecular theory to find an answer.

B. Fill the small bottle with slightly colored water so that when you put on the stopper with the tubing in it, the water will rise about one inch into the tubing. Put the filled bottle into a saucepan with a little water in it and heat it gradually on a hot plate. Observe the water in the tube, and by applying the kinetic-molecular theory, explain what you see. Take the bottle out of the saucepan, let it cool for a few minutes, and then set it in a pan of ice. Observe the results and explain what happens in terms of the kinetic-molecular theory.

C. Put the open end of a toy balloon tightly over the top of an empty pop bottle and place the bottle in a saucepan partially filled with water. Heat it gradually on a hot plate and observe what happens. Take the bottle out of the saucepan, let it cool for a few minutes, and then place it in a pan of ice. What happens? Infer from kinetic-molecular theory an explanation for what you see.

D. Fill 2 pint jars with equal amounts of hot and cold water. With a medicine dropper, one person drops ink into the jar of hot water while the other person simultaneously drops an equal amount of ink into the jar of cold water. Infer from the kinetic-molecular theory an explanation of what you see.

E. Give 3 examples of practical application of the kinetic-molecular theory in your everyday world - excluding the ones in this MOD.

Discuss Brownian Motion, and the motion of the NH_3OH in the air, from a standpoint of the basic assumption of the kinetic theory.

MOD 193 The Chemistry of Nucleic Acids- Self Instructional Module

OBJECTIVES:

1. Name the bases found in DNA and RNA.
2. Describe a nucleoside and a nucleotide in outline form, and draw a nucleotide showing the structure of sugar and phosphate.
3. Draw a dinucleotide.
4. Recognize proper and improper base-pair arrangements.
5. Name the forces that hold polynucleotides together in double-helical structures.
6. Name and describe the difference between DNA and RNA molecules.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on The Chemistry of Nuceic Acid
3. Biology Media instructional materials
4. Singer Caramate

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

INTRODUCTION:

Nucleic acids represent one of the major classes of biological macromolecules... those giant molecules that give form and function to all living cells.

There are two forms of nucleic acids--DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Each form has a unique role in cellular processes. DNA serves as a repository of genetic information; RNA forms the machinery for producing enzymes and other proteins.

In order to tell how DNA and RNA are able to accomplish their complex tasks, we must first describe in detail the structures of these molecules. The purpose of this module is to describe the chemical subunits of DNA and RNA and how these subunits are connected together to form polymeric macromolecules. Other modules (see our list of titles) describe the functions of these nucleic acids and how their functions depend on their specific structures.

OUTLINE

I. DNA
    A. Subunits
        1. Base
        2. Sugar
        3. Phosphoric acid
    B. Polymers
        1. Detail of sugar
        2. Detail of phosphoric acid
        3. Condensation
        4. Formation of dinucleotide
        5. Polynucleotide chains
    C. The double helix
        1. Detail of purines and pyrimidines
        2. Hydrogen bonding: base pairs
        3. Complimentary polynucleotide chains
II. RNA
    A. Subunits
    B. Polynucleotide chains

THE CHEMISTRY OF NUCLEIC ACID

① Nucleic acids are some of the most unusual and the most important compounds in the cell. Their central roles in genetics make their function significant to all fields of biology, and one can best understand their functions when one is acquainted with their chemical structures.

② There are two types of nucleic acids: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

③ DNA is found primarily in the nucleus of eucaryotic cells and the nuclear region of procaryotic cells. It forms the substance of genes -- that is, it carries genetic information in its structure. Some DNA molecules are incredibly long and stringy. The longest one that has been isolated in one piece is about 1.2 mm long and has a molecular weight of almost 3 billion daltons. It is almost certain that other DNA molecules are even larger.

④ In cells, RNA is found primarily in the cytoplasm. There are several types of RNA, all of which play some part in the translation of genes, in the production of proteins. In addition, in some viruses RNA forms the genes. RNA molecules vary in size from small ones of 30,000 daltons to larger ones of several million daltons.

Fortunately, even though DNA and RNA are large, their structures are fairly easy to describe. This is because they are polymers ⑤ , each built of four types of simpler subunits. I am going to begin by describing the structure of DNA. This is the structure that was first suggested by James Watson and Francis Crick ⑥ in their Nobel prize-winning bombshell of 1952-53. Later I will show how similar principles and materials can explain the structure of RNA.

There are three steps to our description of DNA: first, a sketch of the individual subunits; second, a picture of how the subunits hook together to make long chains; and third, an explanation of how two chains can combine to form a complete DNA molecule, a double helix.

The subunits of DNA are called nucleotides. ⑦ Each nucleotide has three parts: ⑧ first, a base -- a complex organic ring structure. The bases of nucleic acids really are basic in solution (that is how they got their name), but that is not why they are important. We will discuss why they are important later. ⑨ There are four types of bases, called A, T, G, and C. We will see them in more detail later, also.

The second part of the nucleotide is the sugar. ⑩ In DNA, the sugar is of a particular type called deoxyribose. ⑪ The deoxyribose sugar is connected to the base.

To complete the nucleotide, we add the third part, ⑫ a phosphoric acid or phosphate residue, to the nucleotide. The phosphoric acid connects by condensation to the sugar.

From this first outline glimpse of DNA subunits we can see how DNA, deoxyribonucleic acid , gets its name: "deoxyribo-" from its type of sugar; and "acid" from the phosphoric acid hooked to the sugar. The "nucleic" comes from the first discovery of DNA as a part of the nucleus of human pus cells.

The next step in the description of DNA is to show how two nucleotides can be hooked together. To do this, we must look at the sugar and phosphate structures in detail.

⑬ The sugar, deoxyribose, has five carbon atoms. We will number them 1', 2', 3', 4', and 5' from right to left so we can talk about them separately. ⑭ Carbons 1' and 4' are hooked together with an oxygen to form a ring. ⑮ Carbon 1' is also attached to the base and to a hydrogen. Carbon 2' is attached to two hydrogens. Carbon 3' is attached to one hydrogen and a hydroxyl (OH) group. Carbon 4' is attached to a hydrogen; and Carbon 5' is attached to two hydrogens and another hydroxyl group.

A phosphoric acid molecule, ⑯ which looks like this (one phosphorus, four oxygen, three hydrogen atoms), can be covalently bound to the sugar by a condensation reaction ⑰ with either one of the hydroxyl groups -- the one on the 3' carbon, or the one on the 5' carbon. You can think of the condensation reaction formally as something like this: a bond forms between the "O" of the hydroxyl and the phosphate "P". At the same time, the hydroxyl "H" and an "OH" from the phosphoric acid are released as a molecule of water. As I said, this can occur at the 3' carbon, ⑱ in which case the result is a 3'-nucleotide, or at the 5' carbon, ⑲ in which case we have a 5' nucleotide.

Now, the phosphoric acid molecule has more than one -OH part that can participate in a condensation. In fact, ther are three, and two of the three can condense with sugars at the same time. ⑳ For instance, her is a diagram of two 5' nucleotides. Arranged in this way, you can see how the phosphate residue on the 5' carbon of the right-hand nucleotide can also condense with the 3' carbon hydroxyl of the left-hand nucleotide. ㉑ In this way, the phosphate forms a bridge between nucleotides. The resulting molecule is a dinucleotide.

Next, notice that we can add another 5' nucleotide ㉒ to the top of the dinucleotide to form a trinucleotide and others ㉓ to either the top or bottom end to form a longer chain of nucleotides. This is a polynucleotide chain or a nucleic acid. In all natural nucleic acids, nucleotides are joined 3' to 5' at every bridge, just like the one in this diagram.

㉔ For polynucleotide chains in solution in cells (at pH 7 or so), the phosphoric acid groups lose their remaining H+. This gives the chain a negative charge along its length. Normally the chain then attracts salt cations ㉕ (like Na+, K+, or Mg++) to partially neutralize the negative charge. It makes the molecule more stable.

When we draw long polynucleotide chains, we usually use shorthand forms. Her are two you might see. ㉖ ㉗ These represent the same structure as before.

The polynucleotide chain that we have just described is the basic basic DNA structure, but it is not the whole DNA molecule. ㉘ A complete DNA molecule contains two polynucleotide chains bound together and twisted around each other in what is called a double helix.

In order to see why and how the two polynucleotide chains stick together, we must look at the structures of the various bases in detail.

There are two general types of bases: (29) large, double-ringed ones called purines, and small, single-ringed ones called pyrimidines. This first slide shows the basic skeletons of these two types of compounds. The next slide, (30) in which we remove the c's from the corners, shows the abbreviations which make them a little easier to write and recognize. Purines are attached to deoxyribose at the nitrogen on the lower right -- pyrimidines at the lower nitrogen. (31) In DNA, there are two different purines: adenine (called A for short) and guanine (called G); and there are also two different pyrimidines: thymine (called T) and cytosine (called C).

Purines and pyrimidines have a trick. Each purine binds to one particular pyrimidine, and each pyrimidine binds to one specific purine. (32) More specifically, A binds to T, and G binds to C. The binding is through hydrogen bonds. To see how this works, let's look at the structures of A and T first. (33) Here is A. Notice that the sugar deoxyribose is attached to the back of the molecule at a nitrogen, and that there is an amino group attached to the "front end", the six-membered ring. (34) Now here is T. The sugar is again attached to a nitrogen, and there are oxygens double-bonded at two places on the ring. (There is also a methyl group over on the right side, but this does not have any functional significance here.) (35) When we show the A and T together and placed correctly relative to each other, it is clear that two hydrogen bonds can form between them: one between the amino groups of the A and the =O of the T, and one between the ring nitrogens of the A and T.

We can see the same principle again by looking at G and C. (36) Here is G. It differs from A by having an oxygen double-bonded at the top of the six-membered ring and by having an amino group also attached to the same ring. (37) Here, next, is C.

It differs from T by having an amino group at the top (and no methyl group at the back). When we put G and C together correctly, we again can form hydrogen bonds. ㊳ This time there are three: one at the top between the =O of the G and the amino group of the C; one in the middle between the ring nitrogens; and one at the bottom between the amino group of the G and the oxygen of the C.

㊴ The next slide compares the A-T and G=C base pairs. No other pairs of these bases will bind tightly together to form the same size and shape structure. A and G, for instance, if combined, would be too large. T and C, if combined, would be too small. G and T could only form one H-bond, and A and C could not form any at all. Thus the A-T and the G-C pairs are the only pairs normally found between these four bases. A is said to be complementary to T; G is complimentary to C.

㊵ Since two complimentary bases can bind together with hydrogen bonds, it is not surprising that two polynucleotide chains also bind together, provided that enough of their bases are complimentary. That, in fact, is what happens. ㊶ A natural DNA molecule has two polynucleotide chains that run along side by side and are hooked together by hydrogen bonds at each base position. In every part of the molecule the opposite bases are complimentary. Each base pair, each set of hydrogen bonds, helps hold the two chains together.

Two complimentary polynucleotide chains held together by complimentary base pairing form a double helix. ㊷ This is because in solution the two chains wind around each other according to bond distances and angles, ㊸ as shown by the fact that this molecular model -- made with proper bond angles and lengths -- will form the helix. It also pulls the bases close together, stacking them like a stack of plates or records and forcing water out from the inside of the DNA molecule. ㊹ You see, the bases are somewhat hydrophobic so that they favor and conformation of the molecule that minimizes the amount of water that gets close to them. The double-helical conformation does just that. When DNA is twisted this way, ㊺ there are ten base pairs for every turn of the helix.

For the final section of this module, I will describe the structure of RNA. This will be easy because it is quite similar to DNA.

The subunits of RNA ㊻ are also nucleotides. They differ from those of DNA however, because they have as sugar a ribose ㊼ instead of a deoxyribose. Ribose-ribonucleic acid ... it is not hard to remember. ㊽ Ribose looks just like deoxyribose, except it has an -OH group on the 2' carbon. This makes it a little less stable chemically but otherwise does not affect its structure or function. One other difference. ㊾ RNA does not contain thymine (T), but as a replacement has a similar pyrimidine, uracil (called "U"). Uracil differs from thymine only by its lack of the methyl group. Otherwise, it is the same. In particular, it hydrogen-bonds to A when forming base pairs.

㊿ Like deoxyribonucleotides, ribonucleotides are joined by phosphate bridges between the 3' carbon of one sugar and the 5' carbon of another. This forms a polynucleotide chain. Most RNA molecules have just a single chain rather than two like DNA. This does not mean that RNA cannot participate in double helices. On the contrary, an RNA chain can form a double helix with another RNA chain or with a single DNA chain, provided that the other chain has complementary bases. More surprising perhaps, (51) mahy RNA chains are known to form double helices within themselves. Two lengths of a chain, when placed side by side as the chain folds, have complementary bases and thus stick together. (52) Some of the examples of this intra-chain helix formation can get very fancy. It may be that this sort of interior twisting is RNA's way of developing a three-dimensional secondary and tertiary structure and thus acting a little like a protein.

The functionally important properties of DNA molecules and many RNA molecules do not depend on fancy twisting, however. They are not supposed to act like proteins. Instead, it is the liniear order of the bases in the polynucleotide chain that makes these nucleic acids unique and useful. This order of bases represents a language or "genetic code" that describes the properties of each cell. Learning to read this language has been one of the spectacular achievements of molecular biology. Learning to write new messages in it is a powerful and frightening capability of the near future.

(53)

GLOSSARY

A (adenine) -- one of two purine bases found in DNA and RNA. In nucleic acids, is complementary to either T or U. Also a component of coensymes like ATP, NADH.

base -- the nitrogenous component of nucleotides and polynucleotide chains. A purine or pyrimidine; A, G, C, T, or U.

complementary -- in general, acting together to complete the whole. In nucleic acids, one base is considered complementary to another is the two form a stable base pair, connected by hydrogen bonds.

condensation -- a chemical reaction in which two substrates are joined with the concurrent formation of one water molecule. The opposite of a hydrolysis reaction. Two nucleotides may be joined by a condensation reaction to form a dinucleotide.

DNA (deoxyribonucleic acid) -- a polymer of deoxyribose-containing nucleotides. Generally found as a double-chained structure, a "double helix." The genetic material of all cells.

deoxyribose -- the sugar component of the nucleotides of DNA. Connects by condensation to two phosphate residues in DNA. Connects to the bases of DNA.

dinucleotide -- two nucleotides connected by a phosphate bridge.

double helix -- the structure of most DNA molecules. Consists of two complimentary polynucleotide chains, bound together by hydrogen bonds and would together in a right-handed helical shape.

G (guanine) -- one of two purine bases found in DNA and RNA. Complementary to C.

nucleic acid -- a polynucleotide chain. A long sequence of nucleotides connected by phosphate bridges. Includes DNA and RNA.

nucleotide -- the subunit of a nucleic acid. Consists of one purine or pyrimidine base, one sugar, and one phosphate, all connected by covalent bonds. The base connects to the 1' C of the sugar; the phosphate may connect either to the 3' or to the 5' C of the sugar.

polynucleotide chain -- a nucleic acid. A long sequence of nucleotides connected by phosphate bridges. Includes DNA and RNA. Might include artificial compounds not found in cells and with no biological function.

purine -- one of the classes of nitrogenous bases found in DNA and RNA. A double-ringed structure containing C, N, H, and sometimes O atoms. Includes A and G, as well as some compounds, like caffeine, not found in nucleic acids.

pyrimidine -- one of the classes of nitrogenous bases found in DNA and RNA. A single-ringed structure containing C, N, H, and sometimes O atoms.

RNA (ribonucleic acid) -- a polymer of ribose-containing nucleotides. The principal nucleic acid found in the cytoplasm of cells. There are several types of RNA molecules, distinguished by their different sizes, shapes, and functions.

ribose -- the sugar component of the nucleotides of RNA. Connects by condensation to the phosphate residues in RNA. Connects to the bases of RNA.

T (thymine) -- one of three pyrimidine bases. Found in DNA, but not RNA. Complementary to A.

U (uracil) -- one of three pyrimidine bases. Found in RNA, but not DNA. Complementary to A.

MOD 194 Geo Blocks

Geo Block activities may be designed to provide experiences with awareness geometry, symmetry, and linear, area, and volume relationships.

OBJECTIVES:

1. You will be able to answer the questions in the Teacher's Guide and verify your answers.
2. You will be able to write challenging questions for a set of geo blocks.
3. You will be able to solve problems posed by the "Problem Cards."
4. You will be able to design problem cards for geo blocks.

INSTRUCTIONAL MATERIALS AND REFERENCES

1. ESS unit, Geoblocks, Teacher's Guide and Problem Cards
2. 8½" x 11" sheets of heavy paper (yellow and blue)
3. Toy car with rolling wheels
4. Boxes, 2 or 3

INSTRUCTIONS:

1. From the Teacher's Guide for Geo Blocks read "Insights" near the front and pages 1-14 for ideas for teaching with geo blocks.
2. Answer the questions under "Flat Shapes," "Slopes," "Grouping," "Outsides," "Amount of Wood," and "Outside/Inside" and verify your answers.
3. Write at least two additional questions appropriate for each of the groups in item 2.
4. Alternate showing your partner appropriate cards and work through the "Problem Cards for Geo Blocks."
5. Construct at least 2 yellow and 2 blue problem cards and laminate.

FINAL ASSESSMENT:

1. The instructor will randomly select questions from the guide for you to answer and verify.
2. You will be asked to solve problems from problem cards.
3. Bring your questions and problem cards to the evaluation session.

MOD 195 Landforms I
Observing, inferring

OBJECTIVES:

1. After studying Ward's Elementary Landform Models #1 through #4 and completing this MOD, you will be able to state plausible inferences as to how the formations occurred. Each inference should be supported by some visible evidence found on the Landform models.
2. After studying the Landform models, you will be able to correlate selected photographic slides of classic landforms to specific starred terms in the lab descriptions.
3. After studying the Landform models, you will be able to answer the selected questions in this MOD, pp. 2-5, and to support those answers with evidence found on the models.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Set of Ward's Elementary Landform Models 1-4
2. Glossary of terms for each Landform model with features starred by the instructor
3. Description of each Landform model
4. Included set of questions
5. Slide viewer
6. Ward's geology slides selected by the instructor--Land Forms I
7. 8 mm. filmloop projector
8. Filmloop, Part One--Canyon Land

9. Film Associates, Offset Along Faults, filmloop #ES/18
10. Film Associates, Folded Mountains, filmloop #ES/6

FINAL ASSESSMENT:

1. See the objectives above.
2. Bring to your instructor the completed MOD sheets to discuss.

PROCEDURE:

Work only with the selected terms in the glossary that are starred to correspond to the photographic slides.

1. For each Landform model (1-4), study the labeled parts and read the accompanying definitions. Then read the description for each model. To give a more realistic picture of each starred landform, a representative photographic slide will be found in the slide tray labeled MOD 195 (see activity 3 below). Also use with this MOD the set of three filmloops titled Grand Canyon Geological Formations, Offset Along Faults, and Folded Mountains. These filmloops will be used as a study source in addition to Model 2, Canyon; Model 3, Fault Block Mountains; and Model 4, Folded Mountains. After you have identified all numbered items for a particular model and after you have read the model description, watch each of these filmloops.

2. Answer the questions included in the following pages for each model.

3. Match the pictures found in the slide tray with the starred terms found in the descriptive sheets which you have just studied. More than one term is correct on some of these slides. List the pictures and forms that you matched on the answer sheet with this MOD.

MODEL 1: COASTAL PLAIN
Slides #3, #4, and #9

1. Notice the delta (8). Why is the city (16) adjacent to this delta instead of being built upon it?

2. Would the river (6) be a relatively fast or slow moving stream? State your evidence.

3. **If a person were to walk on the delta in a downstream direction, would he find the coarser grained sediment at the beginning or end of his walk? Why?**

4. **Give several reasons why the coastal plain would be a good place for farming.**

MODEL 2: COASTLINE OF SUBMERGENCE
Slides #18 and #20

MODEL 3: FAULT BLOCK MOUNTAINS
Slides #1, #6, #13, and #14

5. What happens to the water that flows down from the mountains? State the observations that support your conclusions.

6. The alluvial fans (1) resemble what landform in Model 1?________________
Where does the material in an alluvial fan come from?__________________

7. Why would this whole landform be an area of potential earthquake activity?

8. Notice the many channel scars in the alluvial fan (1). Why do you suppose the streams shift their position so frequently over these alluvial fans?

MODEL 4: FOLDED MOUNTAINS

Slides #2, #7, #12, #13, #15, and #16

14. Because sediment was originally deposited to form the layers of rock seen in this model, the older sediment is seen on the lower levels and the newer or younger layers are evident on top. After millions of years stresses caused the bending and folding of the rocks which is evident in this model. If you cut straight across the top of an anticline (67), would the oldest or youngest beds be exposed in the center? __________ If you cut across a syncline (66), would the oldest or youngest beds be in the center? __________

15. What type of rock seems to be the most easily eroded?

16. If you were standing at the top of an anticline, would the beds be tipping towards you or away from you? __________

17. If you were standing at the bottom of a syncline, would the beds be dipping toward you or away from you?

18. What type of rock is the folded mountain (65) composed of? __________ Is this type of rock more or less easily eroded than the green shale that is directly beneath it?

MOD 197 Template Functions of DNA

OBJECTIVES:

1. State where in the DNA molecules genetic information is carried.
2. Outline the synthesis of DNA; identify the components involved.
3. Outline the synthesis of RNA; identify the components involved; state how this differs from DNA synthesis.
4. Define and distinguish between: nucleoside triphosphate, nucleotide; DNA polymerase, RNA polymerase.
5. Given the base sequence of a messenger RNA, write the sequence of its DNA template.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. This MOD,
2. General Biology references on Template Functions of DNA
3. Biology Media Instructional Materials, includes Slide/Tape
4. Singer Caramate

FINAL ASSESSMENT:

1. See objectives above.

MOD 196 Rational Numbers Extended

OBJECTIVES:

At the conclusion of this MOD you should be able to:

1. Perform rational number computations and explain the basis for each of the skills.
2. List major ideas related to rational numbers developed in each grade level in an elementary textbook series.
3. Represent fractions as ordered pairs and geometrically on a set of coordinates.
4. State and apply the Law of the Trichotomy and the concept of density of numbers.
5. Identify error patterns for decimals made by children, suggest probable causes, and propose activities to remedy the difficulty.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. Ruler
3. Graph paper
4. Elementary mathematics textbook series

INSTRUCTIONS:

1. Review terminology at bottom of page 56 and page 57 of Rational Numbers.
2. Perform Activity 6, Items 1-5 and keep all your records.
3. Activity 18 is identified as "Seminar." However, it may be pursued individually or in pairs. Complete Items 1, 2, 3, and 5 and record your answers.
4. Perform Activity 20, Items 1, 2, 3, 4, 5, 6, 7, and 8. Keep all records.
5. For Activity 21, read the introductory material and perform Items 1, 2, 3, 4, 5, 6 and 7. Keep your records.
6. Perform Activity 32 and keep all records.
7. Prepare a game to reinforce the concepts of this MOD for your permanent file.

FINAL ASSESSMENT:

1. Bring all records and materials to the assessment confernece.
2. Be prepared to discuss your written records.
3. See objectives above.

INTRODUCTION:

In 1953, James Watson and Francis Crick first postulated a double helical structure for DNA. The Watson-Crick model triggered immediate excitement, not only because it provided a logical explanation for some confusing chemical facts about DNA, but also because it suggested how this molecule might accomplish its key functions in the life of the cell.

What were these biological functions of DNA? How could a model for DNA's structure explain its operation? By 1953, experiments on bacterial transformation and on bacterial viruses had shown that genes were made of DNA. And genes, of course, were known (a) to contain or store information about the characteristics of the cell, (b) to reproduce this information and carry it from parent to daughters at every cell division, and (c) to release this information when necessary in order to direct the growth and development of the cell. If genes were made of DNA, then DNA must be able to store information, to reproduce it before cell division, to release it for use in the cell.

Watson and Crick's model provided a way in which DNA might store information: as a sequence of purine and pyrimidine bases connected in linear chains. The model also immediately suggested how DNA's information could be reproduced, how the chains of DNA could provide molds, or "templates", for the construction of new chains. Later, this same template concept explained how information could be transcribed from DNA onto RNA aND used for directing the synthesis of proteins, and thereby control the entire chemistry of the cell.

The purpose of this module is to describe in detail how the structure of a DNA molecule provides the basis for the replication and transcription of genetic information.

OUTLINE: Slide/Tape Presentation

I. Functions of DNA.
II. How does DNA "carry genetic information"?
  A. DNA structure: base sequences.
  B. Letter sequences as information.
III. Reproduction of genetic information.
  A. Watson-Crick theory of DNA replication.
    1. Complementary strands.
    2. Templates.
    3. Replication process: strand separation and construction of new polynucleotides on templates; replication forks.
  B. Electron micrographs of DNA replication.
    1. Virus, E. coli DNA circles.
    2. Replication model for circular DNA.
  C. Enzyme functions in DNA replication.
    1. Enzyme.
    2. Substrates.
    3. Polymerization process.
IV. Transcription of genetic information.
  A. RNA structure.
  B. RNA synthesis.
    1. Enzyme.
    2. Substrates.
    3. Polymerization process.
    4. Promoters.
    5. Electron micrographs.

TEMPLATE FUNCTIONS OF DNA

① ② The concept of the gene was originally designed to simplify the study of heredity. Gregor Mendel defined genes as hypothetical factors that control traits, and he showed that the inheritance of simple traits could be described most easily as a passage of genes from parents to progeny.

Further information and reflection on the nature and functions of genes has complicated this once-simple concept. If genes are real and not just hypothetical, there are many things that they must be able to do. ③ Genes control traits, so each gene must carry or contain the information needed to specify the general and detailed nature of its trait. Genes must help reproduce the genetic information. Why? ④ When a cell divides, its daughter cells must each recieve a complete set of genes, a complete set of genetic instructions. Otherwise they would not be the same as their parent cell: they would not be able to grow or develop or divide again into more daughter cells. If both the two daughter cells are to receive a complete set of instructions, then the original set of genes must be completely and faithfully reproduced. ⑤ Finally, genes must transmit their information to all areas of the cell so that their information can be used to direct the development of the cell. In other words, genetic information must be translated so that it can be expressed as traits, and genes must help in the translation process.

The discovery that genes are made of one type of biochemical macromolecule, DNA, implies that DNA does all the things that genes must do. ⑥ It must be able to carry information, help reproduce that information, and help translate the information. This leads to a first-rate scientific mystery: how can one molecule, DNA or any other molecule, accomplish all these things? DNA seems like a relatively simple, even though large, molecule, with a structure much the same from organism to organism, from species to species. How can it be responsible even for carrying all the instructions in the thousands of genes needed to direct the growth and development of an organism, let alone for the reproduction and translation of these instructions?

⑦ To answer this question, we might take a closer look at the structure of the DNA molecule, for it is possible that its structure could tell us much about how it functions. The structure that is now accepted was first proposed by James Watson and Frances Crick in 1952. They were interested in DNA structure for the same reason we are: they hoped for clues to its genetic functions.

⑧ Watson and Crick hypothesized that DNA was built in the shape of a ladder twisted around itself, a "double helix". ⑨ Two chains, composed of alternating units of deoxyribose and phosphate, formed the two sidepieces of the ladder. Pairs of bases formed the crosspieces, or steps.

The bases were especially important. There were four types of bases, adenine (A), thymine (T), guanine (G), and cytosine (C). Each base was a complex organic molecule, containing one or two rings. Pairs of bases could bind together through hydrogen bonds, but only certain combinations of bases could form pairs: A with T, and G with

C. Because only these combinations of bases fitted together, the sequence of bases on one side of the ladder determined the sequence of bases on the other side. But in general the sequence of base pairs along the molecule was not specified. According to the model, any of four permissible base pairs, A=T, T=A, G=C, C=G, could fit into any of the positions on the DNA ladder.

Interestingly enough, it is the sequence of base pairs that differs from DNA molecule to DNA molecule, from species to species. The deoxyribose-phosphate backbone and general structure stays the same, but the base sequence varies. Since species differ because their genetic information differs, since their genetic information is contained in DNA, and since their DNAs differ only in the sequence of their bases, one can suggest that the genetic information is held in the base sequence of the DNA.

It may not be obvious to you just how a sequence of bases in DNA is supposed to carry information, especially all the information needed to specify the shape, position, and function of every cell in the body of a plant or animal. Maybe this is a good time to consider what information is. Information, the way I am thinking of the term, is a message. Here is a message in English: ⑩ Genes are units of heredity. This English message is made up of letters. There are twenty-six possible letters--maybe more, if your want to count the space, the period, and other punction marks. But the point is that there are only a finite number of letters, yet there are an almost infinite number of messages I could have written. It is possible to write many messages using only a few letters, ⑪ because the message is contained actually in the sequence of the letters and because one can use as long a sequence as necessary to get the message across.

⑫ In exactly the same way, the cell can write messages in DNA. The DNA language has only four letters, the base-pairs A=T, T=A, G=C, and C=G, but by placing these letters in the right sequence, and in as long a sequence as necessary, it is possible to make any message the cell requires.

Since the cell needs lots of information, that is, lots of messages, there must be very long sequences of DNA bases, long stretches of DNA. This agrees with what we know about DNA--it is a long, stringy molecule. The smallest complete DNA genome known comes from a bacterial virus and has 5500 base-pairs. You might think of this more as a paragraph of 800 words, each word seven letters long. Don't you think you could describe a very simple virus in 800 words (assuming, of course, that you knew what the virus looked like)? The DNA of the bacterium, Escherichia coli, is considerably larger. It has about 3 million base-pairs, and it therefore carries more information, more messages. The DNA in a human cell is estimated to have about 5,500,000 base-pairs, seven million times as much as the virus we mentioned. It is admittedly difficult to describe a human being--books have been written trying to do this--but indeed 5,500,000 letters would fill books. We guess that they would provide the correct description, if they were arranged in the right sequence.

If we accept the idea that DNA can carry information in its sequences of base pairs, we must then ask how DNA helps reproduce this information. How can the cell reproduce DNA--that is, make new copies of DNA--and retain in each copy all the information present in the base sequences of the original molecules? The best part of Watson and Crick's model was the fact that it provided a possible mechanism for the reproduction of genetic information.

⑬ The basis of this mechanism lay in the double stranded feature of the model. Remember that each base in one strand could pair with only one kind of base in the other strand ⑭ (A with T, T with A, G with C, C with G). Remember that this fact fixed the sequence of bases in one strand once the sequence in the other strand was chosen. That meant that each single strand carried the total amount of genetic information in its base sequence, put another way, that there were two full copies of genetic information in the double-stranded DNA. The two strands were not identical, of course; they didn't have the same bases. ⑮ Instead they were called "complementary"; they had matching bases. The two complementary strands of DNA bear the same relationship to each other as a ⑯ printed page bears to its type face, ⑰ as a photographic print bears to its negative, ⑱ or as molded pottery bears to its template. ⑲ In fact, each strand could be called a "template" of the other. Each strand has all the information needed to specify the base sequence of the other.

Watson and Crick suggested that the DNA molecule and its base-sequence-information could be reproduced ("replicated") by a process involving ⑳ separating the original strands by breaking the weak hydrogen bonds between matching bases, ㉑ arranging new, complementary bases along the original strands, and ㉒ connecting these new bases together to form new strands. This suggestion was in Watson and Crick's second paper published in Nature in 1953.

Another model ㉓ , very similar to the first, suggested that the separation of the original strands and the formation of new strands occur simultaneously, forming a structure like that shown on this slide. The region of replication, called a "replication fork" would move along the molecule until the entire DNA was copied. This picture is taken from Watson's book, *Molecular Biology of the Gene*. Both this mechanism and the one on the slides before use separated strands of the double helix as templates to form two new molecules identical to the original one.

What do we know about how the replication of DNA really occurs?

For one thing, with modern techniques and an electron microscope we can take pictures of DNA molecules caught in the process of replication. The next two pictures show a viral DNA and a bacterial (*E. coli*) DNA in this situation. You may be surprised when you see them--did you know that some viral DNAs are circles? ㉔ What these micrographs show are double-looped structures associated with the replication of a circular DNA from a virus. On the next slide ㉕ is the same kind of shape seen in a much larger *E. coli* DNA molecule. These pictures are important, because they seem to show replication forks ㉖ , structures predicted by the later Watson-Crick model of DNA replication.

㉗ When a circular DNA replicates, its two strands apparently separate at one point. New DNA strands are formed using the separated originals as templates. The resulting structure now has either one or two replication forks, depending on what kind of DNA it is and what sort of cell it is in. ㉘ At each replication fork, there will be further separation of the parental DNA, followed by further synthesis of new DNA. This will continue until the replication fork has moved completely around the circle.

How is new DNA synthesized at the replication forks?

Like important processes in the cell, DNA replication requires enzymes to work. ㉙ There exists in all cells an enzyme , "DNA polymerase", which functions during DNA synthesis to link together the new bases. DNA polymerase adds bases one at a time to the growing end of a new DNA strand. The actual substrates of this chemical reaction are deoxyribonucleoside triphosphates ㉚ . A deoxyribonucleoside triphosphate is a base with a deoxyribose sugar and three phosphates hooked to the 5' carbon of the sugar. These substrate molecules are made by enzymes in the cell and kept available until they are needed for DNA synthesis.

㉛ The next few slides show how the enzyme DNA polymerase works. In these pictures, the black chain of A and T bases represents the original, template strand of DNA. The red chain represents the new, growing strand of DNA. The green oval with the yellow spot is the enzyme, DNA polymerase; the yellow spot is the enzyme's active site.

The enzyme starts by attaching to the template (black) DNA strand and the growing end of the new (red) DNA strand. ㉜ Then it matches the base of a substrate deoxyribonucleoside triphosphate to the corresponding base on the template strand. Once the substrate is firmly in position, ㉝ the enzyme then hooks the -OH group on the 3' carbon of the growing chain to the inner phosphate of the new deoxyribonucleoside triphosphate, forming the phosphate link between the sugars. The outer two phosphates are released: it is this release of the phosphates that provides the energy for DNA synthesis. The phosphates eventually split up and go into the cell's general pool of phosphate. (34) Finally, the enzyme moves on along the DNA by one base, getting in position to repeat the addition of substrate.

The slides you have just seen represent only one side of the replication fork. What happens at the other side? (35) It seems that events on the other side must be different, because the two new, growing DNA strands face in opposite directions. The strand we have been watching has a free 3' carbon to which DNA polymerase can attach deoxyribonucleoside triphosphates. The other strand has a free 5' carbon, unsuitable for addition of these substrates.

One possible solution to the dilemma is this: (36) after the parental DNA strands separate, the DNA polymerase extends the new strand with the free 3' end by a certain number of bases. The the enzyme turns around, switches templates, and synthesizes DNA back down the other side until it reaches the end of the other strand. A second enzyme (called a "ligase") joins the gap, and now both sides of the new DNA have been extended a short distance. This process, repeated many times, eventually will lead to the replication of the whole DNA molecule.

(37) We now come to the third and final part of this module. You have seen how DNA stores information and how its structure enables the cell to reproduce the information before cell division. But if DNA forms genes, it must be able to perform one more function of genes. It must be able to supply the information to the cell in usable form whenever it is needed.

It does this by serving as a template for the synthesis of RNA.

(38) RNA is a type of molecule which can carry a transcription of genetic information contained in DNA from the nucleus to the cytoplasm.

It does this by having a base sequence complementary to one of the two strands of a DNA molecule. If DNA is the master blueprint for a cell, RNA might be considered a working plan which, after it is used, can be discarded. Such an RNA molecule is called a "messenger" RNA (mRNA). Some other specialized RNA molecules also form parts of the machinery that translates the transcribed message. Whatever their different functions, however, all RNA molecules share some similar physical properties and all are synthesized by a similar mechanism.

Like DNA, RNA is a nucleic acid. How does RNA differ from DNA? RNA is single-stranded; it also has ribose, a slightly different sugar, where DNA has deoxyribose, and it uses uracil (U), a slightly different base, in place of thymine (T). Despite these differences, the bases of RNA can form complementary pairs with those of DNA, if the sequences of the RNA and DNA match.

RNA synthesis is very much like DNA synthesis: (39) RNA is also synthesized by an enzyme, this one called "RNA polymerase". The process also uses DNA as a template and nucleoside triphosphates as substrates. Of course, the substrates are ribonucleoside triphosphates (40), different from deoxyribonucleoside triphosphates in the sugar and in the uracil replacing thymine.

(41) Here is a picture of DNA with an RNA polymerase molecule. The polymerase is represented by the yellow-green blob in the background. (42) For RNA synthesis, the DNA strands separate and the enzyme "RNA polymerase" binds to one template strand, the straight strand in this picture. (43) The enzyme then begins by binding ribonucleoside triphosphates complementary to those in the template DNA strand. After the first one is placed (44), the enzyme moves along the DNA (the

enzyme is moving up the DNA in this description), connecting ribonucleoside triphosphates together, releasing two phosphates at each step. As before, the release of these phosphates provides the energy to make the whole process go. ㊺ As the RNA is formed, it peels away from the DNA and the two strands of the DNA snap back together. This slide shows the DNA-RNA complex after the enzyme has moved quite far along the DNA template. Finally ㊻ , the finished RNA is released from the enzyme and the DNA and is free to leave. Notice that the RNA carries a base sequence complementary to that of the template strand of DNA, and it can carry the sequence anywhere in the cell.

Where does RNA synthesis start? How does the enzyme know which strand of DNA to copy? RNA synthesis can start at many places on a DNA molecule, corresponding to the many genes or groups of genes that have to be translated. ㊼ The spots on the DNA where RNA synthesis starts are called "promoters", but what they look like and how they work is not yet know.

Want to see a picture of RNA as it looks during synthesis? ㊽ This picture is an electron micrograph of RNA extracted from a cell as it was being made on a DNA template. The axis of each feathery structure is the DNA, the gene; the side pieces sticking out are RNA (covered with protein). The RNA pieces are small at the beginning of the gene (the promoter) and larger at the end, where they are almost finished.

Let us end this module by summarizing the important concepts that it proposes:

㊾ First, DNA carries genetic information in long linear sequences of base pairs. Each gene is one sequence of base-pair "letters", something like a sentence in English.

㊿ Second, the two strands of DNA each act as templates during the synthesis of new DNA. The original bases determine the bases that are connected to growing new DNA chain, and thus the old base sequences determine the base sequences of the new DNA. The structure of DNA thus helps to guarantee that new genetic information is a faithful reproduction of the original genetic information.

(51) Third, at least one strand of DNA acts as a template for the formation of RNA. The genetic information in the base sequences of DNA is thus transferred to base sequences of RNA, in which form it can be used to direct the formation of new cell material and thus determine the characteristics of cell and organism. (52)

GLOSSARY

base--the nitrogenous component of nucleotides and of DNA and RNA. The bases A,T,G, and C are found in DNA; A,U,G, and C are found in RNA.

base pair--two complementary and connected bases occupying corresponding positions in the two chains of a DNA double helix; one "letter" in a DNA "message".

base sequence--the order in which bases are positioned along an RNA chain or base-pairs are positioned along a DNA double helix.

complementary--in general, acting together to complete the whole. In nucleic acids, one base is considered complementary to another if the two form a stable base-pair connected by hydrogen bonds.

DNA (deoxyribonucleic acid)--a polymer of deoxyribose-containing nucleotides. Generally found as a double-chained structure, a "double-helix". The genetic material of all cells.

DNA polymerase--an enzyme responsible in part for the synthesis of new DNA. The enzyme uses deoxyribonucleoside triphosphates as substrates; in the synthetic reaction it adds the nucleotide part (deoxyribonucleoside monophosphate) of the substrate to the 3' end of a DNA chain, releasing the remaining two phosphates to solution.

deoxyribose-phosphate chain--the backbone of DNA; the part of the DNA that holds base-pairs in linear sequence. Made of alternating units of deoxyribose and phosphate.

deoxyribonucleoside triphosphate--a substrate for DNA synthesis. Consists of one base, deoxyribose, and three phosphates, all connected by covalent bonds. The base connects to the 1' carbon of the deoxyribose; the three phosphates are connected together in a line, and the line is connected to the 5' carbon of the deoxyribose.

double helix--the structure of most DNA molecules. Consists of two deoxyribose-phosphate chains connected to a linear series of base pairs and wrapped around these base pairs in a right-handed helical shape.

gene--an element inside a cell or organism that controls one trait; in molecular terms, a segment of DNA which serves as a template for the formation of one RNA molecule or (through a messenger RNA) of one protein molecule.

ligase--an enzyme involved in the synthesis of DNA. Works by connecting together segments of deoxyribose-phosphate chains.

promoter--the region of DNA that initially binds to RNA polymerase; the region of DNA at which RNA synthesis begins.

RNA (ribonucleic acid)--a polymer of ribose-containing nucleotides. The principal nucleic acid found in the cytoplasm of cells. There are several types of RNA molecules, distinguished by their different sizes, base sequences, and functions in the cell.

RNA polymerase--the enzyme responsible for the synthesis of RNA. The enzyme binds to DNA, using one strand as a template for the RNA synthesis. The enzyme uses ribonucleoside triphosphates as substrates; in the synthetic reaction it adds the nucleotide part of the substrate to the 3' end of the RNA chain, releasing two phosphates to solution.

replication--reproduction of DNA; the process by which a parental DNA, DNA polymerase, and deoxyribonucleoside triphosphates form two DNA molecules, each identical to the original parent.

replication fork--a region of DNA in which parental DNA separates and new DNA is synthesized using the parental DNA strands as templates.

ribonucleoside triphosphate--a substrate for RNA synthesis. Consists of one base, ribose, and three phosphates. The base connnects to the 1' carbon of the ribose; the three phosphates are connected together in a linear chain, and the chain is connected to the 5' carbon of the ribose.

template--a pattern for testing accuracy of form; in biology, a sequence of monomeric units (e.g., bases) connected together into a polymer and used to direct the joining of another sequence of monomeric units into another polymer.

transcription--synthesis of RNA; the process by which the base sequence of DNA is "transcribed" into a base sequence of RNA.

MOD 198 Metric Measurement in the Outdoor Environment

This MOD is designed to provide additional experience with metric measurements, particularly those for large measurements in the out-of-doors. Exercises are also provided with scales, graphing, and conversion from one system to another.

Although conversions should not be emphasized when teaching metric measurement, because often measurements are reported in one system and the need is in another system, one should be able to make the conversion when needed.

OBJECTIVES:

At the completion of this MOD you should be able to:

1. Measure linear distances using a metric tape, trundle wheel, or your own step.
2. Make scale drawings using metric measurements.
3. Calculate perimeters and areas of objects for which you have made linear measurements for the dimensions.
4. Read a Celsius thermometer and discuss results observed during experimentation with freezing and boiling points of water solutions.

INSTRUCTIONAL REFERENCES & MATERIALS

1. Globe, string, metric ruler, large sheets of cardboard, masking tape, knife or scissors, 100 lengths of soda straws, each 1 dm, hot plate, Celsius thermometer, sugar, salt, ice, trundle wheel
2. Task cards 7, 11, 18, 43, 56, 57, 59, 60
3. Three booklets: "How to Choose the Right Tool to Measure Distance," "How to Make a Conversion Graph," "How to Use a Trundle Wheel," and "How to Make a Scale Drawing."
4. Duplicator Masters 14 and 31, "How Are Changes in Linear Measurements Going to Affect You?" and "How Are Temperature Measurement Changes Going to Affect You?"

FINAL ASSESSMENT:

1. Bring all work to the evaluation interview.
2. Be prepared to discuss and explain your work.

PROCEDURES:

1. Scale Drawings in Metrics
   Make a metric scale drawing of the SME Resource Center or the ISMEP Laboratory in Mason Hall.
2. Estimating and Measuring Long Distances in Metric Units
   - a. Estimate the distance between two adjacent light poles on the West side of Mason Hall.
   - b. Find the average length of your stride and use this information to find the distance between the two adjacent light poles. (For instructions for determining the length of your stride see Task Card 11.)
   - c. Use a trundle wheel to measure the distance between the light poles.
   - d. Use the metric tape to measure the distance between the light poles.
   - e. Which measurement is likely most accurate? Which is least accurate? Why?

3. Metrics in Athletics
   Do either Activity 1, 2, or 3.
   Activity 1: Metric Baseball
   - a. Using a trundle wheel or metric tape, measure the baselines on a baseball diamond.
   - b. How far in metric units would you have to hit a metric home run at the MSU baseball field?
   - c. Construct a neat scale drawing for the baseball field. Identify your scale.

   Activity 2: Metric Basketball
   - a. Using a trundle wheel or metric tape, measure the dimensions of the basketball court.
   - b. What is the metric area of the court?
   - c. How far in metric units would you have to run if you ran 20 laps around the perimeter of the basketball playing court?
   - d. Construct a neat scale drawing for the basketball court. Identify your scale.

   Activity 3: Metric Football
   - a. Using a trundle wheel or metric tape, measure the dimensions of the football field.
   - b. What is the metric area of the playing field?
   - c. What is the perimeter of the playing field?
   - d. Construct a neat scale drawing for the football field. Identify your scale.
4. Relationships between Perimeter and Area
   Do Task Card 18.
5. Metric Temperature Measurement
   1. Do Task Cards 57 and 60.
   2. Choose either Task Card 56 or 59.
6. Extended Metric Activities
   Choose Task Card 7 or Task Card 43 and carry out the activities.
7. Conversion from One System to Another
   obtain copies of Duplicator Masters 14 and 31 from the file cabinet and complete them.

MOD 198

Name ______________________ Date __________

HOW ARE CHANGES IN LINEAR MEASUREMENTS GOING TO AFFECT YOU?

Teacher's Note: Students will get more direct involvement with the linear measures in everyday life than any other measure. They should become very proficient in all of the common units.

PROBLEM: Find the relationships between metric and customary measurements.

DIRECTIONS

Read carefully and fill in the blanks with the correct answers.

1. Speed limits will change!
   a. A 50 miles per hour speed limit will become an 80 kilometers per hour speed limit.
   b. A 15 mph speed limit will become a ________ km/hr speed limit.
   c. A 35 mph speed limit will become a ________ km/hr speed limit.
   d. Plot a graph which will allow other conversions.
2. Distance signs between cities will change!
   a. If a sign says "Flagstaff 10 miles" it will become "Flagstaff 16 kilometers."
   b. If a sign says "Denver 100 miles" it will become "Denver ________ km."
   c. If a sign says "Spokane 30 miles" it will become "Spokane ________ km."
   d. Plot a graph to make other conversions.
3. Sports measures will change!
   a. What would be an appropriate unit for measuring the high jump metrically?
   ____
   b. In metric units what would be the approximate world metric high jump record?
   ____
   c. The mile-run distance is approximately ________
   d. What is the approximate metric measure of a football field? ________________.
   e. How high is a basketball goal in metric units? ________________.
4. Instead of buying cloth by the yard you will buy it by the ________.
5. Clothing sizes will change! Instead of a 26-inch belt, you would buy a 65-________ belt.
6. Thirty-inch shoelaces will become 75-________ shoelaces.
7. The height of a mountain will be expressed in ________.
8. What other linear measures will change? Answers will vary.

EXTENSION: Have students develop a list of "will change" items.

Duplicator Master 31

MOD 198

Name ______________________________ Date ________________

HOW ARE TEMPERATURE MEASUREMENT CHANGES GOING TO AFFECT YOU?

Teacher's Note: Students will have a hard time making accurate estimates of temperature and and will need a great deal of practice making estimates.

PROBLEM: Find the relationship between the metric and customary temperature measurements.

DIRECTIONS

Read carefully and fill in the blanks with the correct answers.

1. When it is zero degrees Celsius, that means water A is going to ________.
2. Forty degrees below ________ will remain the same. *Note:* −40°C = −40°F.
3. If you take your temperature and it is up to ________, call the doctor!
4. When baking in an oven, the degrees ________ temperature will read approximately one-half the Fahrenheit scale.
5. A cake that bakes at 360°F would bake at ________°C.
6. A high of ________ on the 4th of July in Miami, Florida will take some getting used to.
7. The number of below zero days that occur will ________.
8. Room temperatures will feel good when the thermostat is set to ________.
9. When your automobile radiator is boiling, what degrees Celsius temperature will the guage record ________.
10. When it is 40°C in Phoenix, Arizona, what should you be wearing? ________________
11. Temperatures between ________ and ________ are great for being outdoors doing things.

EXTENSION: Make a list of temperature changes you are going to experience.

MODULE 199 MISSING FROM DOCUMENT PRIOR TO ITS BEING SHIPPED TO EDRS FOR FILMING.

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MOD 200 Self-Concept

Because self-concept plays such a major role in school behavior and learning, especially in mathematics, this seminar is designed to introduce you to self-concept theory and to increase your ability to transfer this knowledge to day by day situations with students.

OBJECTIVES:

Upon completion of the self-concept workshop activities you will:

1. Show awareness of personal feelings and of the feelings of others.
2. Become active in analyzing and responding to situations based on personal awareness.
3. Be aware of self-concept theory.
4. Be able to transfer knowledge of self-concept theory to day by day situations with students.

INSTRUCTIONAL REFERENCES AND MATERIALS:

All materials will be provided at the scheduled seminar.

FINAL ASSESSMENT:

Satisfactory completion of the MOD will be accomplished by your attending and participating in the scheduled workshop.

MOD 201 Populations (SCIS)
Defining operationally

OBJECTIVES:

After the completion of this MOD you will be able to:

1. Identify and operationally define:
    - a) populations
    - b) predator-prey
    - c) plant eater
    - d) animal eater
    - e) plant-and-animal eater
    - f) food chain
    - g) food web
2. Discover predator-pray relationships existing in the Environment Boxes you build.
3. Distinguish between a plant eater, an animal eater, and a plant-and-animal eater.
4. Name food chains existing in the Environment Box and illustrate food chains and food webs which exist in your environment.
5. Describe and discuss the factors which tend to stabilize population numbers.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SCIS, Populations, Teacher's Guide, Part II, pp. 46-63
2. Environment Box prepared by the student
3. Biology: An Appreciation of Life, CRM Books, Chapter 14
4. Biology the World of Life, Wallace Chapter
5. Self Instructional Module -"The Ecosystem I: Introduction"

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

1. Read and study SCIS, Populations, Teacher's Guide, pp. 46-63.

2. Follow instructions on page 48 for building your terrarium.

3. One week after planting your seeds add cricket and aphid populations to your terrarium (see pp. 51-52).

4. One week after adding the cricket and aphid populations to your terrarium add a chameleon to your terrarium (see pp. 55-58).

5. Make daily observations of the populations in the Environment Boxes during the entire three-week period. Record your observations below using meaningful and descriptive terminology about these populations.

   List organisms in the Environment Boxes which would be classified under:

	Plant Eater	Pea Eater	Clover Eater	Animal Eater	Plant-and-Animal Eater
1					
2.					

6. Name some of the factors in a predator-prey relationship which contribute to stable population numbers.

7. By observing the populations, what inferences can you make about their physiological needs? Their food preferences?

8. Draw a food web below which you think exists in the Environment Box. Be prepared to give logical support for your food web diagram on the basis of the observations you made.

9. How does the food web which you think exists in the environment box differ from those described in the self-instructional module?

How are they similar?

7. Identify and operationally define:

   a. Populations

   b. Predator-prey

   c. Plant eater

   d. Animal eater

   e. Plant-and-animal eater

   f. Food chain

   g. Food web

PAGES 5-6 OF MODULE 201 "THE COMMON HOUSE CRICKET"
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THE ECOSYSTEM I: AN INTRODUCTION

An ecosystem is the pattern of interaction among organisms and their environment in a particular area. An ecosystem may be large or small, complex or simple, composed of many plants and animals or few. Ecosystem interactions consist of getting food, competition, using nutrients, seeking shelter, etc.

Interactions involving the flow of energy and materials determine the basic structure of the ecosystem. Energy and material are obtained from food. Some organisms make their own food. Others get food from other organisms. The structure and function of the ecosystem can be approached by studying relationships involving food-food chains, food webs, and trophic pyramids. The food relationships between organisms make up the trophic ("feeding") structure of the ecosystem.

This presentation introduces the ecosystem by outlining the basic principles of ecosystem trophic structure. The following objectives outline essential points you should master.

OBJECTIVES

-- describe typical interactions which are involved in ecosystem structure and function.

-- give examples of typical ecosystems.

-- describe the functional relationship between autotrophs and heterotrophs.

-- given a habitat and list of organisms, outline an ecosystem in terms of food chains, food webs, and trophic levels.

-- describe the trophic level of a given species.

-- explain the significance of food in ecosystem structure and function.

-- describe the functions of producers, primary consumers, secondary consumers, and decomposers in the ecosystem.

-- define the following terms: ecosystem, community, abiotic, biotic, autotroph, heterotroph, producer, consumer--primary, secondary, tertiary, decomposer, food chain, food web, trophic level.

OUTLINE OF MODULE

- I. Introduction
  - A. Interactions among organisms
  - B. Definition of ecosystem
    - 1 boundaries
  - C. Examples of ecosystems
  - D. Basic patterns
    - 1. biotic and abiotic
    - 2. flow of energy and materials

- II. Structure of forest ecosystem
  - A. Based on food
  - B. Producers -- plants
  - C. Consumers -- animals
  - D. Food chains
  - E. Food web
  - F. Decomposers
  - G. Heterotrophs and autotrophs

  Question: Meadow food chain and web

- III. Trophic levels and pyramids
  - A. Trophic levels
  - B. Pyramid of numbers
    - 1. description
    - 2. examples
    - 3. limitations
  - C. Pyramid of biomass
    - 1. description
    - 2 examples
    - 3. limitations
  - D. Pyramid of energy flow
    - 1. description
    - 2. how it differs from other pyramids
    - 3. why it is always upright?

① THE ECOSYSTEM I: INTRODUCTION

② The natural landscape is made up of many habitats: ③ forests, ④ lakes, ⑤ mountain tops, ⑥ rocky shores, ⑦ even campuses and ⑧ freeways. Each of these habitats holds its own forms of life. ⑨ In the forest around our campsite we might find (besides trees) squirrels, mice, a variety of insects, an owl, maybe even a bear. The forest isn't just a hodge-podge. We wouldn't expect to find a camel or a jellyfish or a cactus out there. The forest has a structure. The plants and animals are related to one another in definite ways.

⑩ The chickaree lives in the forests of the Sierra Nevada of California. It eats pine cones. ⑪ It also depends on the pine tree as an escape route ... perhaps to escape from the hawk, ⑫ which depends on squirrels and other small animals for its diet. The chickaree, the hawk, and other animals depend ⑬ on the plants of the forest for oxygen as well as for food. The plants depend on the animals for some of their carbon dioxide. Also, some plant seeds are dispersed by clinging to the coats of animals or in the digestive tracts of animals. ⑭ The whole system depends on the weather, and materials like soil, minerals, water, and air. ⑮ The energy of sunlight makes the whole thing go by making the plants grow.

⑯ This elegant natural system -- the pattern of interactions among organisms and their environment -- is called an *ecosystem*. Ecosystems can be large or small. ⑰ An aquarium would be a good example, ⑱ or a pond, ⑲ or a desert, ⑳ or even the whole world. This giant ecosystem is often called the biosphere.

From the standpoint of an ecologist, ㉑ even the organisms inside an insect-eating plant ㉒ or a human being and his parasites may be considered ecosystems.

The boundaries of some ecosystems are more distinct than others. The boundaries of the human ecosystem, ㉓ a lake, or forested island are fairly easy to define. ㉔ But some ecosystems, like this area of chaparral scrub in California, are hard to separate from their surroundings. The chaparral plants gradually blend in with the plants of surrounding desert and mountain ecosystems. The animals of the chaparral move freely into other ecosystems; so sometimes it is hard to say how big an ecosystem is ... where one ecosystem ends and another begins.

Each ecosystem is unique in its pattern of interacting plant and animal populations. ㉕ This living or biotic part of the ecosystem is sometimes called a community; and thus sometimes we speak of forest or tidepool communities. Each ecosystem is subject to a particular combination of nonliving or abiotic factors. ㉖ Lack of moisture shapes the desert. ㉗ Strong winds affect the plants and animals on high mountains.

Ecosystems differ greatly from one another -- an aquarium is very different from a desert -- but there are structural and functional concepts which apply to all ecosystems. ㉘ These concepts mostly involve the flow of energy and materials through the ecosystem. This short presentation introduces the ecosystem. It concerns the basic principles of ecosystem structure and function. Two succeeding units discuss energy and materials in the ecosystem.

㉙ Interactions involving energy and materials determine the major pattern of the ecosystem. To organisms, energy and materials mean food: making food and getting food. Let's take a closer look at food in the forest ecosystem. Note that the principles of ecosystem structure which we will discuss apply to all other ecosystems as well.

㉚ Through photosynthesis, trees and other plants convert the energy of sunlight into the energy of chemical bonds. Carbohydrates, fats, and proteins are manufactured from raw materials in water, air, and soil. The green plants are thus the producers for the ecosystem -- they convert the nonliving into the living -- they package energy and organic matter which can be used by other organisms. ㉛ The deer obtains energy and materials by browsing on grass and twigs. It uses these materials for growth or reproduction or it breaks down the material or uses the energy stored in the food materials. ㉜ The mountain lion gets its energy and materials by consuming other animals. In contrast to the plant producers, the deer and mountain lion are consumers. ㉝ Think back to the chickaree which eats pine cones, and the hawk which eats chickarees. Each of these similar food pathways is called a food chain. ㉞ Each food chain consists of plant producers and animal consumers. The food chain has a set structure -- the mountain lion can't short-circuit the chain and eat grass; and the squirrel can't turn the tables and devour a surprised hawk. Finally, food chains are not infinite in length. They are usually limited to five or fewer links. We'll discuss why later.

㉟ There are many, many other food chains in the forest ecosystem. For instance: wildflower to butterfly, to lizard, to hawk. Thus the hawk is at the top of two food chains. ㊱ Similarly, the squirrel might be preyed upon by the fox as well as a hawk. ㊲ Thus, food chains are interconnected to form food webs. Here's a highly simplified forest ecosystem food web. Remember, when looking at food webs, that each organism on this chart actually represents a population of organisms. The butterfly may represent several thousand butterflies. There may be a hundred squirrels in our patch of forest; maybe half a dozen owls.

In addition to producers and consumers there is a third very important biotic component of the ecosystem. ㊳ These are the decomposers ... organisms which break down and recycle materials in wastes and dead bodies. ㊴ Bacteria, fungi and other decomposers clean up when a fox marks his territory or a mountain lion gets filled up before he cleans up his plate. ㊵ There may be 30 billion bacteria to do this job in every pound of forest litter.

㊶ Producers make their own food. They are often called autotrophs -- "autotroph" meaning "self-feeding." Consumers and decomposers get their food from other organisms. They are called heterotrophs -- a word meaning "other-feeding."

Now stop the tape and sketch a meadow food chain. Add a couple of connections to form a simple food web. Check this out with your instructor or a sample answer; then restart the tape.

㊷ We can arrange our food chains and food web to represent the number of links in each chain, or the number of energy and material transfers in each chain ... sort of like steps or levels. ㊸ These are called trophic levels. The plants are of course producers The butterfly and deer are primary consumers. The lizard is a secondary consumer. The hawk is a secondary consumer if it eats a squirrel, and a tertiary consumer if it eats an insect-catching bird. Primary consumers are also called herbivores because they eat herbs. Higher consumers are carnivores. They eat meat. Many consumers are omnivores -- they can eat plant or animal food. Human beings, for instance, are omnivores. Remember, these are called trophic levels. The food web is sometimes called a trophic web. The food web structure of the ecosystem is sometimes called its trophic structure.

㊹ The relative numbers or amounts of living things at each trophic level are sometimes represented in the form of a pyramid -- with the size of each step proportional to the organisms at that level. This is a pyramid of numbers describing a grassland ecosystem. There are a million and a half individual plant producers, but only one tertiary consumer per every quarter acre of grassland. Don't worry about the absolute numbers here. Just note that there are many producers and fewer and fewer consumers.

㊺ Pyramids of numbers are not generally applicable, however. There are problems with this kind of description of the ecosystem. Imagine a forest situation where relatively few trees are fed upon by many insects. ㊻ The insects outnumber the trees, so the pyramid of numbers is partially inverted. Thus, the numbers pyramid is not very useful for making comparisons between ecosystems ... it is not consistent.

㊼ The limitations of the pyramid of numbers can be overcome, however, if we compare the mass of organisms at each level, rather than sheer numbers. The mass of living material is called biomass.

This corrects the forest pyramid: even though there aren't as many trees as insects, the amount of plant material weighs more than the insects.

㊽ This is a pyramid of biomass for a freshwater spring in Florida.

㊾ Now take a look at this pyramid of biomass for the open ocean of the English Channel. Phytoplankton producers are on the bottom and zooplankton consumers on top. How can 4 grams of plants support 21 grams of animals? It's interesting you should ask. The pyramid of biomass has its problems too. It leaves out the dynamic, changing aspects of the situation. This pyramid tells you that at any given moment, if you were to dip a net into the waters of the channel, you would find 4 grams of plants per square meter with 21 grams of animals per meter gobbling them up. What the pyramid doesn't tell us is that the producers in this case have a tremendous reproductive rate which enables them to keep ahead of the consumers. The rapid production of plant material is disregarded in the static pyramid of biomass. Thus, the pyramid of biomass is also of limited usefulness. Its shape is not consistent from ecosystem to ecosystem.

㊿ The most accurate representation of the relationships between ecosystem trophic levels is the pyramid of energy flow. The pyramid of energy flow describes the rate at which calories of food energy pass through the food web, from trophic level to trophic level.

This energy pyramid for a Florida spring shows that for a given period of time and area, about 21,000 calories of production energy are corrected to about 3,400 calories of primary consumer energy, etc.

(51) The energy pyramid accurately describes the relationships

and relative importance of the trophic levels, and it is most useful in comparing the structures of ecosystems. Interestingly, the energy pyramid is always upright. (52) Why is the energy pyramid always rightside up? Why does the amount of energy decrease at each level? These are fascinating questions. These questions were our reason for discussing pyramids in the first place. (53) To explain the energy pyramid, we must understand how energy gets into the ecosystem, how it is used, and where it ends up. We will discuss energy in the ecosystem in the second ecosystem presentation, concerning energy flow. (54)

MOD 202 Theory of Numbers I

This MOD is designed to expand your knowledge of number theory and to provide you with ideas and techniques for activities in the elementary classrooms.

OBJECTIVES:

After you have completed this MOD, you will be able to:

1. Represent any counting number as a product of prime factors
2. Use tests for divisibility by numbers 2 through 11
3. Use the sieve method to determine the prime
4. Find the GCF and LCM by using prime factorization

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Number Theory
2. Cuisenaire rods
3. Minimum of 20 tiles
4. Fundamental Concepts of Elementary Mathematics by Lawrence A. Trivieri

PROCEDURE:

1. View slide-tape Overview of Number Theory.
2. In the MMP book, Number Theory, do:
   Activity 1: Read Discussion and do Sections 1, 2, 4, and 5
   Activity 2: Part A, Sections 1, 2, 3, 4, and 5
   Part B, Sections 1, 2, 3, 4, and 5
   Activity 3: Part A, Sections 1, 2, 3, 4, and 5
   Part B, Sections 1 and 2
   Part C, Sections 1 and 3i and 3ii
   Activity 4: Fill in table on page 37 (If necessary, consult Trivieri's Fundamental Concepts of Mathematics, pp. 236 - 245 in Resource Center) 1a, b, c, d and 2a, b. Do not write in book.
   Activity 5: Part A, Sections 1, 2, 3, 4, 5, and 8a
   Activity 6: Part A, Sections 1 and 2
   Part B, Sections 1, 3, 4, and 5
   Part C, Sections 1 and 3

FINAL ASSESSMENT:

Schedule an interview and bring all papers to the evaluation session.

SELF-TEST for MOD 202

1. A number is divisible by 4 if and only if ______________________________

____

2. A number is divisible by 9 if and only if ______________________________

____

3. Does $7 | 6944$? _____ Show test.

4. Does $6 | 294,462$? _____ Show test.

5. Does $8 | 294,462$? _____ Show test.

6. Find the greatest common divisor of 52 and 60.

7. Find the least common multiple of 52 and 60.

8. Factor 36 into its prime factors by the factor tree method.

9. Find all the primes less than 50 by the sieve method.

10. If $120 = 2^3 \cdot 3 \cdot 5$ and
$180 = 2^2 \cdot 3^2 \cdot 5$, then the l.c.m. of 120 and 180 is _____?

Answers to SELF-TEST, MOD 202

1. The last 2 digits of the number are divisible by 4.

2. The sum of the digits is divisible by 9.

3. Yes, $\begin{array}{r} 694 \\ \underline{8} \\ 686 \end{array}$ $\begin{array}{r} 68 \\ \underline{12} \\ 56 \end{array}$ $7|56 \Rightarrow 7|6944$

4. Yes, since $2|2$ and $3|27$.

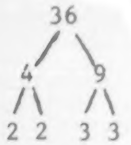
5. No, since $8 \nmid 462$.

6. $52 = 2^2 \cdot 13$

   $60 = 2^2 \cdot 3 \cdot 5$

   g.c.d. $= 2^2$

   L.c.m. $= 2^2 \cdot 3 \cdot 5 \cdot 13$

8. 

   $36 = 2^2 \cdot 3^2$

9. $\cancel{1}$ 2 3 $\cancel{4}$ 5 $\cancel{6}$ 7 $\cancel{8}$ $\cancel{9}$ $\cancel{10}$ 11 $\cancel{12}$ 13 $\cancel{14}$ $\cancel{15}$ $\cancel{16}$ 17 $\cancel{18}$ 19 $\cancel{20}$

   $\cancel{21}$ $\cancel{22}$ 23 $\cancel{24}$ $\cancel{25}$ $\cancel{26}$ $\cancel{27}$ $\cancel{28}$ 29 $\cancel{30}$ 31 $\cancel{32}$ $\cancel{33}$ $\cancel{34}$ $\cancel{35}$ $\cancel{36}$ 37 $\cancel{38}$

   $\cancel{39}$ $\cancel{40}$ 41 $\cancel{42}$ 43 $\cancel{44}$ $\cancel{45}$ $\cancel{46}$ 47 $\cancel{48}$ $\cancel{49}$

10. $2^3 \cdot 3^2 \cdot 5$

MOD 203 Interaction and Systems (SCIS)
Observing, inferring, interpreting data

OBJECTIVES:

1. Given two sets of materials, you will work with them in order to demonstrate the meanings of each of the following:
    a. interaction
    b. evidence of interaction
    c. system
2. Given the activities carried out for objective 1, you will list and describe examples of 3 different kinds of interaction-at-a-distance.
3. Given the activities carried out for objective 1, you will select materials of your own choice and demonstrate the meanings of interaction, evidence of interaction, and system in terms of your materials.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Interaction and Systems, Teacher's Guide
2. Pulleys, baseboards, cranks, shafts, copper chloride, bags made from coffee filters, glass containers, aluminum foil, plastic bags, filter paper

FINAL ASSESSMENT:

1. Show your records for activities 1, 2, and 3.
2. See objective 2.
3. See objective 3. With real materials, be prepared to demonstrate for the instructor the concepts stressed in this MOD.

PROCEDURE:

These activities refer to chapters in SCIS, Interaction and Systems, Teacher's Guide.

1. Read "Objects Interact" and "Systems," pp. 28-30, 44-48, as preparation.

2. Read "Exploring Pulleys" and "Comparing Pulley Systems," pp. 66-69, and work with the pulleys and bases supplied in the MOD tray. Write your observations and use the pulleys to demonstrate interaction, evidence of interaction, and system. What happens when you put one twist in the string or rubber band around two pulleys? Write any relations or inferences you reach by manipulating the pulley systems.

3. Read "Dissolving," "Making Copper Chloride Solution," and "Aluminum and Copper Chloride Solution," pp. 70-79, and work with the chemicals supplied in the MOD tray. Write your observations and use the chemicals to demonstrate interaction, evidence of interaction, and system. Carry out the activities described in the SCIS Teacher's Guide, pp. 70-79, and record your results below.

4. Read "Interaction-at-a-Distance," pp. 80-81, and list at least 3 specific cases of interaction-at-a-distance in your everyday world excluding the effect of magnets on each other and on iron.

   1.

   2.

   3.

   Others

5. Use real materials other than those in the MOD tray to demonstrate the meanings of interaction, evidence of interaction, and system.

MOD 204 Environments (SCIS)
Observing

OBJECTIVES:

1. After completing this MOD, you will be able to define:
   - a) environment
   - b) environmental factors
   - c) range
   - d) optimum range
   - e) minimum } in relation to range
   - f) maximum } in relation to range
2. You will observe an environment and use your data from that environment to discuss the environmental factors and optimum range for some of the organisms in that environment.
3. You will observe and/or infer interactions among the organisms in the environment and the interactions between the organisms and their environment. Be ready to discuss these interactions.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SCIS, Environments, Teacher's Guide, pp. 22-23, 34-35, 40-42, 68-69, 84-85
2. Environment Box prepared by the instructor
3. Hand lens
4. Biology: An Appreciation of Life, CRM Books, Chapter 14
5. Biology the World of Life, Wallace Chapter

FINAL ASSESSMENT:

1. Review briefly procedures 2-6 with the instructor.
2. Discuss the conclusions which you have drawn about the environment and support your conclusions with evidence.

PROCEDURE:

1. Read and study SCIS, Environments, Teacher's Guide pages indicated above.

2. Make daily observations of the animals in the Environment Box for at least two weeks. Record your observations in meaningful and descriptive terminology.

3. Make daily observations of the botanical aspects of the Environment Box for at least two weeks. Record your observations in meaningful and descriptive terminology.

4. Make daily observations of the physical environment in the Environment Box for at least two weeks. Be quantitative in describing your observations.

5. Record below the interactions you detect between any one organism and its environment. Record this for at least three different organisms.

6. Define these terms in view of your study of the Environment Box and your readings:
   - a) Environment
   - b) Environmental factor
   - c) Range
   - d) Optimum range

7. Draw at least one conclusion generalized from your data about the total environmental system of the Environment Box. Support your conclusion with logical evidence.

MOD 205 Theory of Numbers II

This MOD is designed to extend and reinforce your knowledge of number theory and to provide you with ideas and techniques for teaching clock arithmetic in the elementary classroom.

OBJECTIVES:

After you have completed this MOD, you will be able to:
1. Determine the remainder classes for any integer.
2. Recognize and use a set of remainder classes for any given integer as a mathematical structure.
3. Understand and apply the concept of congruence.
4. Define an equivalence relation and show that congruence is an equivalence relation.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Number Theory
2. Minimum of 20 tiles

PROCEDURES:

In the MMP book, Number Theory, do:
1. Activity 10; 1, 2, 3 a, b, c, 4
2. Activity 11; 1, 2, 3, also Project 6
3. Activity 12; Part A, 1, 5, 6, 7
   Part B, 2, 4, 5, 6
   Part C, 1, 3

FINAL ASSESSMENT:

Take written test obtained from Mrs. Yoo in Resource Center.

MOD 206 Subsystems and Variables (SCIS)
Communicating, controlling variables

OBJECTIVES:

1. Given 2 physical systems different from each other, you will work with them in order to demonstrate the meanings of the following:
    a. subsystem
    b. solution
    c. evaporation
    d. histogram
    e. variable
2. Given the activities carried out for objective 1, you will select materials of your own choice and demonstrate the meaning of the 5 concepts listed in objective 1.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Subsystems and Variables, Teacher's Guide
2. Salt, sugar, starch, baking soda, cobalt chloride, filter paper, food coloring, glass containers, empty tea bags
3. Whirly Bird, rivets, graph paper

FINAL ASSESSMENT:

1. Show your records for activities 1, 2, and 3.
2. See objective 2. With real materials, be prepared to demonstrate for the instructor the concepts stressed in this MOD.

PROCEDURE:

These activities refer to chapters in SCIS, Subsystems and Variables, Teacher's Guide.

1. Read the following pages as preparation:
   "Subsystems," pp. 34-35;
   "Solutions and Evaporation," pp. 50-53;
   "Histograms," pp. 72-73;
   "Variables," p. 97.

2. Solutions: Read "Inventing the Solutions Concept," pp. 58-59. Using the materials in the MOD tray, demonstrate the meaning of each term and write a brief description of the results:

   A. Solution

   B. Non-solution

   C. Filtration

   D. Evaporation and crystallization

   E. A solution subsystem of a non-solution

3. Whirly Bird: Read "The Whirly Bird System," pp. 90-105. Using the materials in the MOD tray, demonstrate the following and, if applicable, write a brief description of the results in each case:

   A. Subsystem

   B. Variables

   C. Histogram: Construct one and be ready to discuss it with the instructor Be creative in selecting your variables.

D. Controlling variables

4. Using real materials of your own choice, demonstrate the meanings of: subsystem, solution, evaporation, histogram, variable.

MOD 207 Ecosystems (SCIS)
Inferring

OBJECTIVES:

- A. Given your observation of the Environment Box, you will be able to:
    - 1. discuss what part any one of the following constituents has in maintaining the total system:
        - a) ecosystems
        - b) pollutant
        - c) water cycle
        - d) oxygen-carbon dioxide cycle
        - e) food-mineral cycle;
    - 2. discuss the exchange of materials in an ecosystem in oxygen-carbon dioxide, food-mineral, and water cycles;
    - 3. describe the cycles of a water molecule from the time that it leaves the ocean through evaporation until it returns to the ocean through the ground water, streams, or rivers;
    - 4. discuss the relationship that exists between carbon dioxide, oxygen, water, organic compounds (carbohydrates, lipids, proteins), and metabolism (respiration and photosynthesis);
    - 5. name the five major ecosystems (biomes) seen in the Environment Box.
- B. Utilizing the self instructional modules, "The Ecosystem II: Energy," and "The Ecosystem III: Materials," you should master the ideas described in the self instructional module booklets.

INSTRUCTIONAL REFERENCES AND MATERIALS: (No MOD tray for this MOD, check in Resource Center for items #1,2,3,5)

1. SCIS, Ecosystems, pp. 22-23, 42-43, 58-59, 78-79, and 82-85
2. Biology: An Appreciation of Life, CRM Books, Chapter 14
3. Biology the World of Life, Wallace Chapter
4. Environment Box prepared by the instructor
5. Self Instructional Modules, "The Ecosystem II: Energy" and "The Ecosystem III: Materials"

FINAL ASSESSMENT:

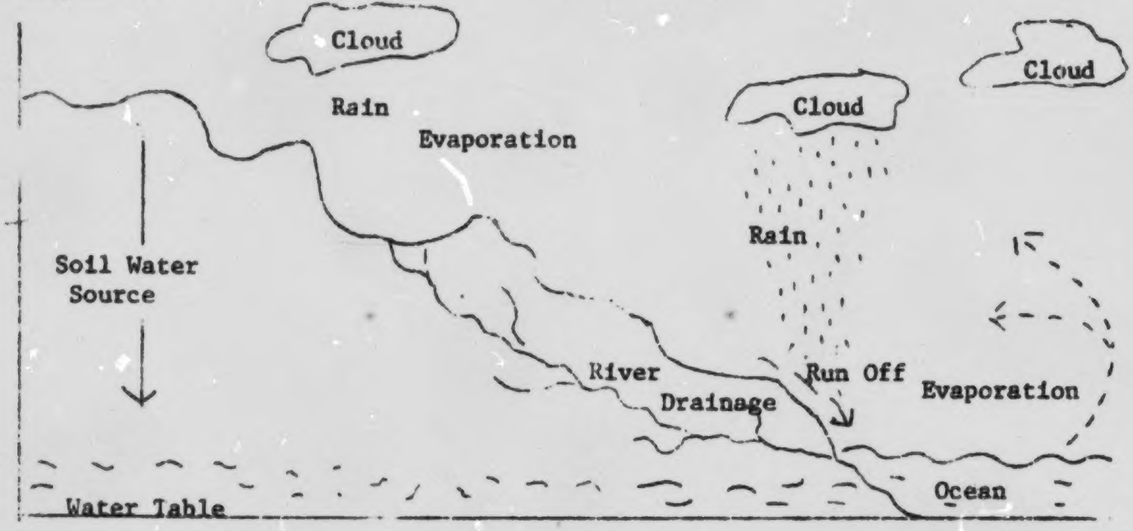
1. See objectives above.
2. Trace the water molecule through several pathways from the time the water molecule leaves the pond in the Environment Box through evaporation until it returns to the pond.

PROCEDURE:

Living organisms are composed of various chemical substances. Water comprises 60-80% of living cells. Water is constantly taken in and voided by the organism. It is used to build body structures, as a carrier for voiding wastes, and to dissolve or put into solution other substances that the organism needs.

It is important then for the living organism always to have water available. Water evaporates into the air from bodies of water such as rivers, streams, or oceans. It drops back on the land in the form of rain. Eventually most of this water re-enters rivers, streams, and lakes or runs back to the ocean. Before this water returns it may be used many times. This MOD shows how water is used and manipulated by living organisms from the time it falls as rain until it returns to our lakes and oceans.

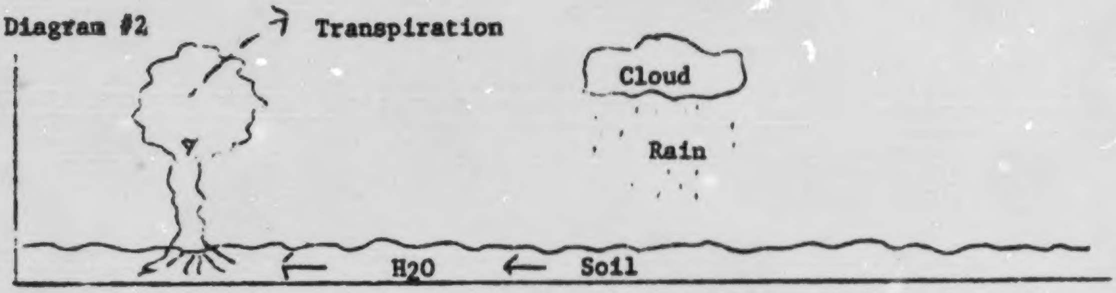
Diagram #1



1. Water constantly enters the air by evaporation from large bodies of water. Water vapor forms clouds. It results in rain which falls upon the earth.
2. Water returns to the ocean in four main ways:
   a. Direct run-off
   b. Indirect run-off by way of streams and rivers
   c. Evaporation from inland waters to form clouds and to rain back into the ocean
   d. Seepage of soil water to underground water tables which move into streams or directly into the ocean

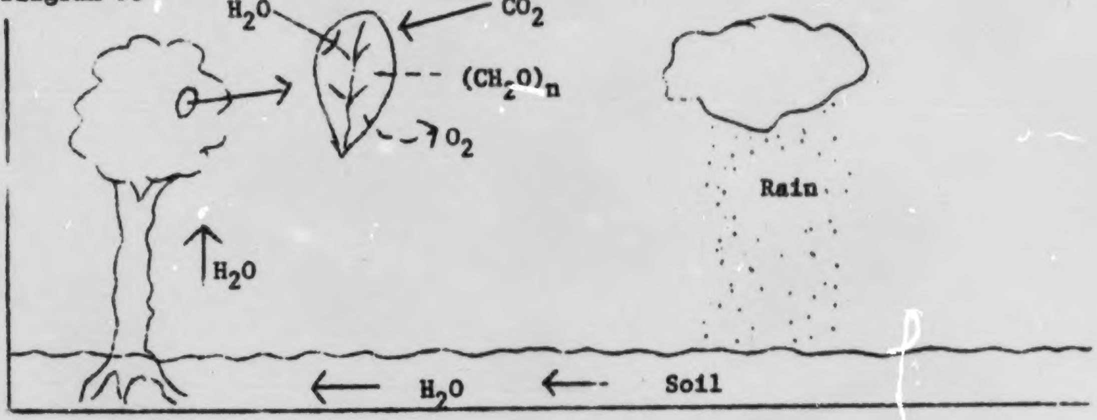
MOD 207

Diagram #2



Plants use water as a carrier to move dissolved substances from the soil to their leaves. Excess water evaporates from leaves by a process called transpiration.

Diagram #3



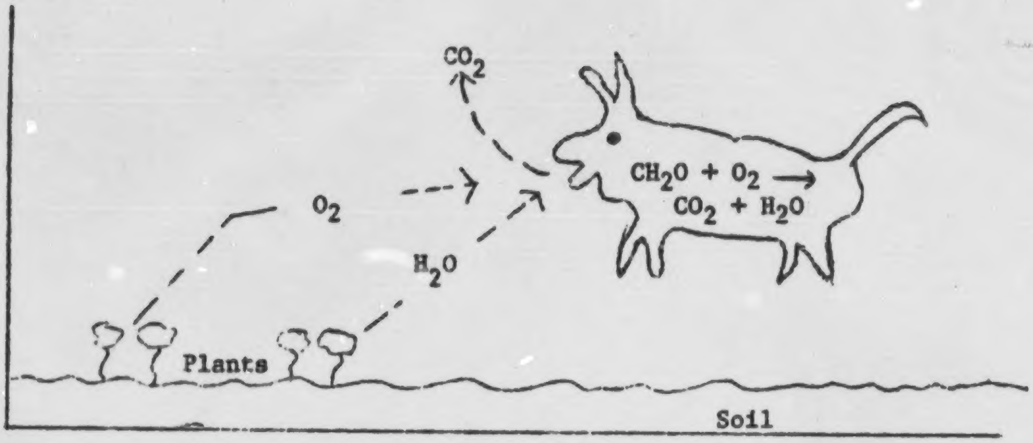
Sunlight on water molecules in plants causes the molecules to break up into hydrogen and oxygen. Hydrogen combines with CO_2 to make organic molecules (CH_2O) such as sugars, starches or proteins. Oxygen diffuses from leaves and enters the atmosphere as oxygen gas. This process called photosynthesis can be expressed by simplified equations.

$$2H_2O \xrightarrow{\text{sunlight}} 4H + O_2 \text{ (gas)}$$

$$2H + CO_2 \longrightarrow (CH_2O)_n$$

In this way some of the water molecules are trapped temporarily in plant tissues. Oxygen enters the atmosphere.

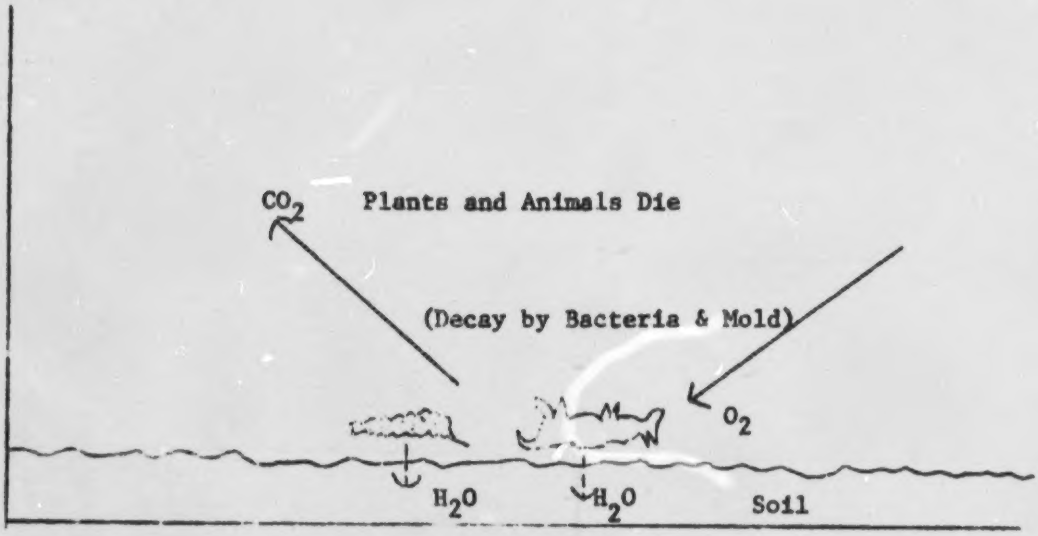
Diagram #4


CO_2
O_2
H_2O
$CH_2O + O_2 \rightarrow CO_2 + H_2O$
Plants
Soil

Animals eat plants or other animals who have eaten plants. These animals break down organic compounds and use them as energy for motion or to make other chemical substances. The breakdown of these organic substances requires oxygen and results in the formation of carbon dioxide and water. Water may be excreted and added to the environment or it may be used for other body functions. The chemical reactions are represented below:

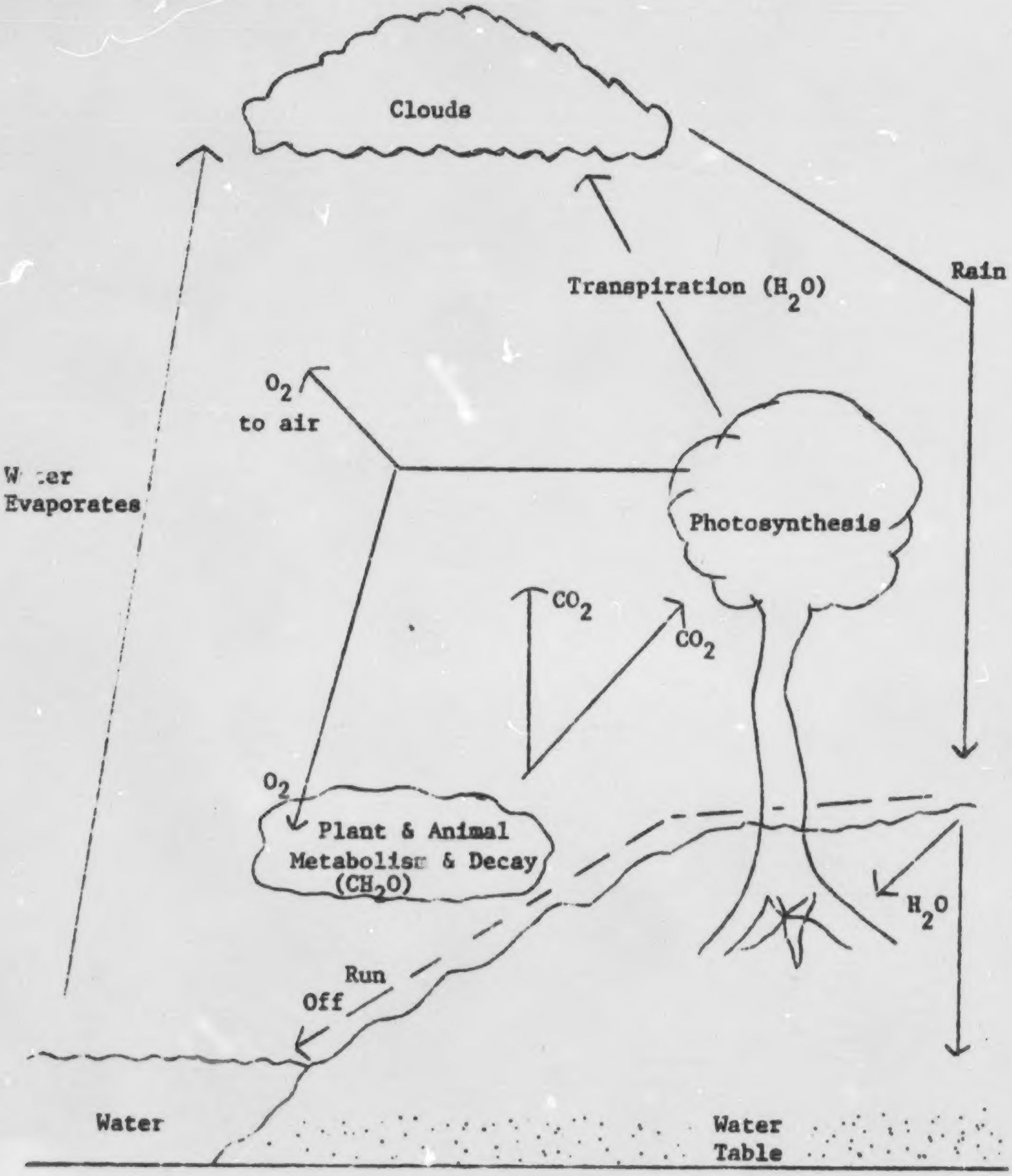
Oxygen + Organic Foods (CH_2O) $\longrightarrow$ $CO_2 + H_2O$ + Energy

Diagram #5


CO_2
Plants and Animals Die
(Decay by Bacteria & Mold)
O_2
H_2O
H_2O
Soil

When plants and animals die bacteria decompose them into carbon dioxide and water. Bacteria combine oxygen with hydrogen from organic materials to form water. Much of the oxygen formed by plants from water in photosynthesis returns to the environment in this way. This water drains into larger bodies and may once again return to the land.

Diagram #6 Water, CO_2, and O_2 Cycles


Clouds
Rain
Transpiration (H_2O)
O_2 to air
Water Evaporates
Photosynthesis
CO_2
CO_2
O_2
Plant & Animal Metabolism & Decay (CH_2O)
H_2O
Run Off
Water
Water Table

THE ECOSYSTEM II: ENERGY

INTRODUCTION

Organisms require a continual input of energy to maintain organization and to power day-to-day activities. The flow of energy from one organism to another is of central importance in determining the structure of an ecosystem.

Energy enters the ecosystem in the form of solar radiation. It is transferred from one trophic level to another in the form of chemical bonds. All the energy which enters the ecosystem as sunlight eventually leaves the system in the form of heat.

The flow of energy through the ecosystem--how it is captured, what it is used for, and the efficiency of transfer--is the subject of this presentation. The following objectives outline the essential points you should master.

OBJECTIVES

-- explain why energy is of central importance in determining the structure of an ecosystem.

-- describe how energy gets into the ecosystem, and identify the source of energy.

-- describe two major "uses" of energy by organisms.

-- describe what respiration or maintenance energy is used for.

-- describe two kinds of production.

-- characterize the ecosystem in terms of the extent to which energy is recycled.

-- give the estimated efficiency of energy capture in photosynthesis and estimated efficiencies of energy transfer between trophic levels.

-- explain the consequences of the above efficiencies as related to ecosystem structure.

OUTLINE OF MODULE

I. Introduction and review

II. A brief overview of energy flow
  A. The "black box" approach
  B. Energy input and output
  C. Producers
    1. some energy is captured, some not
    2. uses of captured energy
  D. Primary consumers--how they use energy
  E. Secondary consumers

III. How the pocket mouse uses energy
  A. Some wasted
  B. Some used to power body processes
  C. Some used for production

IV. Energy flow in more detail
  A. Solar energy strikes plants
    1. most reflected
    2. a small amount stored in chemical bonds
    3. most of the chemical compounds broken down by the plant itself
    4. a tiny amount--production--available to next trophic level
  B. Primary consumers eat plant production
    1. Some plant material not eaten or wasted
    2. Some energy from plants used for maintenance
    3. Production
  C. Efficiency of transfer
  D. Secondary consumers

V. Energy pyramid
  A. Structure related to amount of energy transferred level-to-level
  B. Sun-primary consumer-secondary consumer-etc.
  C. Sun-corn-cow-boy (and implications for feeding the world)

VI. "Wasted" energy
  A. Some eaten by worms, insects, etc.
  B. All leftover chemical energy finally used by decomposers
    1. released as heat
    2. some ecosystems mostly decomposers

VII. Conclusion
  A. Review
  B. Some energy may be exported
  C. Some energy may be imported
  D. The city
  E. Stored energy
    1. growth and development of system
    2. sediments

VIII. How do materials move through the ecosystem?

① THE ECOSYSTEM II: ENERGY

② ③ ④ ⑤ ⑥ In the first part of this three-part presentation on the ecosystem we looked at the trophic structure of the ecosystem: food chains, food or trophic webs, trophic pyramids. ⑦ We asked why the pyramid of energy flow is always rightside up. That is: ⑧ Why does the amount of energy decrease from level to level as it goes up the trophic pyramid, from trophic level to trophic level?

⑨ To answer this question we will have to look closely at how energy gets into the ecosystem; how the energy is transferred from one trophic level to the next; how it is used; and where the energy finally ends up.

⑩ In our examination of energy flow we will study the desert, a strange and beautiful ecosystem. But the basic principles of energy flow apply not only to the desert, but to all natural and managed ecosystems.

⑪ To get started, let's use an approach familiar to systems analysts and engineers, called the "black box" approach. Energy flow between organisms and trophic levels is rather complicated, so at first we will not consider what goes on inside the organisms. We will treat them as "black boxes". We can see what goes in and what comes out, but what goes on inside each black box remains a mystery. Once we get the basics down, we will look inside the boxes for some of the details.

⑫ Energy enters the ecosystem as solar radiation. It leaves as heat. If we were to examine our ecosystem black box closely, we would note that (if the system is not growing or exporting energy) the amount of energy radiated by the ecosystem as heat is equal to the input of sunlight.

⑬ In other words, a certain number of calories of energy goes in as sunlight, and an equal number of calories escape as heat. Because energy passes through the ecosystem and is not reused, the ecosystem is said to be an open system with regard to energy.

⑭ Let's look inside the ecosystem black box and imagine smaller boxes representing the populations of organisms at each trophic level.

⑮ At the producer level, a large amount of the incoming solar radiation is not captured by the plants. It is reflected or merely heats up the vegetation. Some of the solar energy is used by the plants for photosynthesis -- to build complex chemical compounds. Most of these compounds are broken down by the plants themselves, and the energy contained in them is eventually given off as heat. A small amount of the compounds is stored in growth and reproduction. These calories are available to the next trophic level -- the primary consumer level.

⑯ The primary consumers, represented by a pocket mouse and a grasshopper, don't even touch a certain porportion of the plant material. Of the plant material that is eaten, some energy is lost in the consumer's waste products. A large amount of the energy is eventually lost as heat. Some energy is stored in the tissues of the primary consumers. This stored energy is passed on to the next trophic level, ⑰ say, when a rattlesnake or hawk eats a mouse.

At the secondary consumer level some of the mouse energy goes to waste ... the chemical energy of the bones, for instance. Of the food energy consumed by the predators, some is lost as body wastes, some is radiated as heat, and again only a small fraction is stored.

⑱ Let's take a closer look at the pocket mouse and see exactly what happens to the chemical food energy he gets in his diet of seeds.

⑲ Some of the chemical energy stored by the plants is not even eaten by the mouse -- the hard shells on certain seeds, for example. ⑳ Some of the chemical energy of the seeds is lost to the mouse in his urine and droppings. ㉑ Many of the nutrients in the seeds are broken down in the process of cellular respiration, and the ATP molecules produced used to move muscles, power never impulses, move molecules through membranes, and repair body structures. This energy was used to maintain the mouse's activities, so it can be called maintenance energy.

㉒ Finally, a small fraction of nutrients are used as raw materials or energy sources for the growth of mouse tissues or the formation of baby mice. This energy, stored in growth or reproduction, is called production energy.

㉓ Thus, at each trophic level, energy which is not wasted is used for maintenance (and lost as heat), or stored in growth and reproduction.

By now you should be getting an idea why the amount of energy moving through the ecosystem decreases as it goes up through the trophic web. ㉔ Let's abandon our black boxes and reexamine the system. This time we will put in some crude numbers so we can look at the relative amounts of energy involved.

㉕ To start things rolling, sunlight strikes the plants. Let's start with 10,000 calories of solar radiation. Most of this energy bounces off. ㉖ A small amount, one to five per cent or 500 calories, is used by a plant in photosynthesis to build complex compounds such as glucose from simpler raw materials. ㉗ Most of this energy, about 400 calories' worth, is used by the plant itself for maintenance. The chemical energy is used to power cellular processes such as membrane transport and cell division. These 400 calories are eventually lost as heat.

㉘ Some of the stored energy goes into production -- that is, growth of the plant and the production of new plants. The energy stored in production totals about 1/10th of one per cent to one per cent of the sunlight which originally hit the plant, or 100 calories. ㉙ These 100 calories are available to the primary consumer level.

As we noted, the pocket mouse does not even eat some of the plant material available. ㉚ Of the plant tissue ingested by the mouse, some of the calories are excreted in the chemical bonds of materials in the urine and feces. A total of about one half of the available production is either not eaten or wasted by the primary consumers. Where does this energy go? You might think about where it goes. We will return to this topic later.

㉛ Of the 50 calories actually used by the mouse, most of the energy is used in maintenance -- muscular movement and so on. Now we can see why the amount of available energy decreases as we go up the trophic pyramid. At each trophic level, much of the energy is either wasted or used by the organisms themselves just to keep going. ㉜ This leaves only a fraction of the energy for the next trophic level, and so on.

In the case of the mouse, about 10 calories are stored ... ㉝

10 calories out of the 100 calories in food available to the mouse. The pocket mouse is thus about 10 percent efficient at transferring energy from the producer level to the secondary consumer level. ㉞ An ecologist once put it this way: "A mouse is 10 per cent efficient at turning cheese into cat food." Efficiencies of all trophic levels above the producer level average about 10 per cent, although they may run as high as 30 to 40 per cent, or as low as one per cent. ㉟ In our desert ecosystem, the lark, a secondary consumer, is about 10 per cent efficient in turning grasshoppers into hawk food.

㊱ Here is the whole story so far. At each trophic level, some energy goes to waste; a lot is used for maintenance; and some is stored as production. It is easy to see why many top consumers are intelligent, highly mobile predators ... they really have to scramble for the few calories left at the top of the trophic pyramid. The loss of energy at each step also explains why most food chains are limited to five or fewer links. There is simply not enough energy left for higher predators. —

㊲ Now we can construct our trophic pyramid of energy. In doing so, let's look at the efficiencies of entire trophic levels. The plants convert about one per cent of the incoming solar radiation into food for desert tortoises, grasshoppers, and mice. The plants are about one per cent efficient in trapping solar energy. The primary consumers are about 10 per cent efficient in turning plant material into food for secondary consumers, and so on.

㊳ What all this means is: For every 10,000 calories of energy which fall on the plants of the ecosystem, about 100 calories of plant food are available to primary consumers, such as rabbits.

Ten calories of primary consumers can be converted into one calory of secondary consumers, such as foxes or owls. Or: (39) 10,000 calories of sunshine make 100 calories of corn, which make 10 calories of cow. Made into hamburgers, this makes one calory of boy. (40) Note that if the boy eats corn instead of hamburgers, ten calories of boy can be supported on the same amount of corn. As the world becomes more crowded, many of us may have to become vegetarians in order to support more people on our limited area of farmland.

(41) Now, what about all that energy that went to waste? The energy of tough plant parts and animal bones and waste products? (42) Is this wasted energy just piling up?

No, it is not accumulating some place. You have probably figured this out already. (43) Some of this energy is temporarily side-tracked to support scavengers such as insects and worms burrowing through the soil. (44) (The early bird catches not only the worm, but some energy which was not caught by other consumers.) (45) Eventually, though, decomposers such as fungi and bacteria break down waste chemicals to simpler compounds (such as carbon dioxide and water), releasing the final few stored calories in the process. The last bit of waste chemical energy is used by the decomposers for maintenance and eventually given off as heat.

(46) The decomposers use and release much of the energy which flows through the ecosystem. In fact, in some ecosystems, most of the plant production goes directly to decomposition. In these ecosystems the animals familiar to us handle only a tiny fraction of the total energy flow.

(47) Now the explanation of our black box is almost complete.

㊽ Sunlight falls on the ecosystem. Some of the solar energy is stored in chemical bonds. Some of these chemicals are burned by the plant; some chemical energy is transferred to the next trophic level. At each trophic level some energy is lost as heat. At each transfer, some energy is lost. Decomposers break down wastes and release the last bit of energy. Eventually nearly all the energy is lost as heat.

Of course, an ecosystem's energy books are not always balanced. ㊾ A bird which eats its fill and then migrates out of an ecosystem takes some energy with it. This is one example of energy export. ㊿ Similarly, a leaf which floats downstream into an ecosystem imports energy. Some ecosystems import or export a great deal of energy. Few ecosystems are totally self-contained, with no import or export.

(51) The human and animal populations of a city, of course, depend on imported energy. Little food is grown in the city. (52) We get our energy at the supermarket.

(53) Often we find that an ecosystem is taking more solar energy than we can account for in terms of heat and export. In such an ecosystem, production energy is accumulating -- the ecosystem may be growing. This is the case when a forest gradually invades a meadow. The amount of energy stored in the plants and animals of the meadow gradually increases. Eventually, the forest reaches maturity, and energy output equals input.

(54) Sometimes extra production energy is buried. Our fossil fuel reserves are composed of stored production energy from ecosystems of the past. (55) Does that make our cars primary and secondary consumers?

(56) All through this presentation we have considered energy transfer in terms of chemical structures, first formed in photosynthesis, and then transferred from one trophic level to the next. Chemical compounds such as sugars and fats carry energy, (57) as evidenced by the calories in a chocolate sundae. (58) But if we look at our ecosystem black box, we see input and output of energy, but no net input or output of the chemicals which can carry energy. These materials seem to stay inside the box. (59) How do chemical materials move through the ecosystem? What maintains the supplies of materials used by organisms, and what exactly are these materials used for?

(60) These and other questions are the topics of the third part of our presentation which considers the movement of materials through the ecosystem. (61)

THE ECOSYSTEM III: MATERIALS

INTRODUCTION

Organisms require chemical compounds as sources of chemical energy and building materials. Many organisms, such as plants, are capable of manufacturing nearly all of the chemical compounds they require. Other organisms, such as human beings, must get many complex compounds from the environment. But all organisms depend on large pools of simple chemical compounds for raw materials. Materials are constantly being changed from one form to another through the action of biological and physical processes. The amount of each element or compound is finite; each must be recycled. The constant conversion and reconversion of materials as they move through the biosphere constitute material cycles.

This presentation examines some of the materials cycles and the principles covering the movement of materials through the ecosystem. The following objectives summarize the important points you should master.

OBJECTIVES

-- describe two roles played by materials in the ecosystem.

-- describe the movement of carbon through a typical ecosystem.

-- list and describe the three major pools of the carbon cycle. Compare the relative sizes of these pools.

-- briefly describe three transfer processes of the carbon cycle and which pools are connected by these processes.

-- describe a major effect of technology on the carbon cycle, and the danger posed by this effect.

-- describe an ecosystem in which carbon cycling is slow, and another in which carbon cycling is fast. Give the reasons for the difference between these two ecosystems.

-- explain in what way a few simple organisms are important to the cycling of nitrogen in the biosphere, and why all other organisms are dependent on them.

-- describe the major effect of technology on the nitrogen cycle.

-- characterize the ecosystem in terms of the extent to which materials are recycled.

-- compare the movement of energy and materials through the ecosystem.

-- explain the phrase "spaceship earth".

OUTLINE OF MODULE

- I. Introduction
  - A. Review
  - B. Photosynthesis
  - C. Respiration
- II. A typical ecosystem--Yosemite Valley
  - A. Movement of carbon
    - 1. plants
    - 2. primary consumers
    - 3. uses of materials
    - 4. predator
    - 5. decomposers
  - B. Closed system
- III. The carbon cycle
  - A. Pools and transfer processes
  - B. Interconnected ecosystems
  - C. The whole cycle: the sedimentary pool
    - 1. the cycle
    - 2. burning of fossil fuels; possible consequences
  - D. Rates of carbon cycling
    - 1. tropical rain forest
    - 2. fir forest
- IV. Other cycles
  - A. Other cycles
  - B. Nitrogen cycles
    - 1. atmospheric pool
    - 2. nitrogen-fixing organisms
    - 3. agriculture
  - C. Other cycles
  - D. Question: Sketch the oxygen cycle.
- V. Review
  - A. General review
  - B. "Spaceship Earth"

① THE ECOSYSTEM III: MATERIALS

② ③ ④ This presentation is concerned with the movement of materials through the ecosystem. ⑤ The first two units in this series have discussed the trophic structure of the ecosystem and energy flow through the system.

⑥ The ecosystem is an open system with regard to energy. ⑦ Energy enters the system as sunlight, is transferred from trophic level to trophic level as chemical energy, and finally leaves as heat.

Energy is transferred between trophic levels as the potential energy of chemical bonds. ⑧ These bonds are formed in photosynthesis, when carbon dioxide and water are combined to form glucose, with oxygen gas as a byproduct. Other molecules -- such as complex sugars, fats, and proteins -- are built from glucose and other simple molecules. The plants themselves break down some of these organic compounds. Animals consume some by eating the plants and each other.

⑨ The compounds are broken down by the plants and animals in the process or respiration, and the chemical energy is released. CO_2 and water are reformed. ⑩ Energy has been trapped, used, and released as heat. But the original CO_2 and H_2O remain to be used again.

⑪ Let's follow the movement of the carbon in CO_2 through a typical ecosystem -- the forest-meadow ecosystem of Yosemite Valley, California. ⑫ Trees and other plants trap carbon dioxide in photosynthesis, making sugars and other compounds. ⑬ Some of these molecules are "burned up" by the plants in respiration, returning carbon to the atmosphere as CO_2. ⑭ Some of the carbon in the plants is transferred to the primary consumer level -- for instance, when a squirrel eats an acorn. ⑮ The squirrel uses some of the carbon-containing compounds from the acorn in respiration, and CO_2 is released to the atmosphere. Some carbon is lost in the squirrel's waste products, and some is stored in the tissues of the squirrel.

In the squirrel, we can see the two major functions of materials in the ecosystem: Chemical compounds are used as energy sources and as building materials. ⑯

⑰ When a predator such as the coyote eats the squirrel, ⑱ the organic carbon of the squirrel is used in respiration (and lost as CO_2), lost in waste products, or stored in the body tissues of the coyote.

⑲ When the plants and animals excrete wastes or die, bacteria and fungi use the material for energy and building materials. They break down the remaining carbon-containing compounds and return the carbon to the atmosphere as CO_2. Through the action of the decomposers, materials are recycled. Without them, the ecosystem would soon run out of materials. Thus, unlike energy, materials are reused in the ecosystem. The amounts of available materials are limited, and the compounds are used over and over. With regard to materials, the ecosystem is a closed system.

⑳ To simplify our study of the cycling of carbon, we can lump the carbon into pools -- various places or forms in which carbon is found. One pool is the atmosphere, where carbon exists as carbon dioxide gas. This is called the atmospheric pool in the diagram. The organisms make up another pool, where carbon is contained in organic molecules. This pool is called the biotic pool.

㉑ Carbon moves from the atmospheric pool to the biotic pool in photosynthesis. ㉒ It is transferred from the biotic pool back to the atmospheric pool when CO_2 is released as a product of respiration. ㉓ Photosynthesis and respiration are the transfer processes by which carbon moves from one pool to another. ㉔ The movement of carbon between pools is called the carbon cycle because the movement of carbon is cyclic.

㉕ Of course, the CO_2 given off in respiration in the forest is not entirely recycled by the trees of the forest. In the air above the forest, the CO_2 is mixed with CO_2 from other ecosystems. ㉖ The materials cycles of very few ecosystems are entirely closed or isolated, like the cycles in a sealed, "balanced" aquarium. The cycles of various ecosystems interconnect. ㉗ A crab on the ocean shore may respire CO_2 which is used by a tree in the mountain forest. ㉘ You may eat a hamburger which contains carbon from an Iowa corn field.

㉙ Another carbon pool should be added to our diagram. There is a tremendous quantity of carbon which lies buried in the form of coal, oil, and carbonate rocks. This carbon was stored in the bodies and shells of organisms which lived millions of years ago. This carbon trapped in ancient sediments makes up the sedimentary pool.

㉚ Here are the sizes of the pools in billions of metric tons. (The diagram omits the carbon dissolved in seawater and stored in marine organisms.)

㉛ Under "natural" conditions, transfer of carbon between the sedimentary pool and the other pools would be rather slow, ㉜ but modern humans have found it necessary (or at least desirable) to use the energy and materials contained in these ancient sediments to support technological civilization. One environmentalist put it this way: "Industry is subsidized by fossilized dinosaur dung." We are using up fossil fuels much, much faster than they could ever be replaced. We call it the "Energy Crisis."

㉝ In addition, carbon dioxide (and other pollutants) are released in large quantities when fossil fuels are burned to run machines. We have thus greatly increased the rate of transfer from the sedimentary pool (the largest pool) to the atmospheric pool (the smallest). This results in a 0.7 parts per million yearly increase in the amount of CO_2 in the atmosphere; which is considerable since the amount of CO_2 in the air is only a few hundred parts per million.

㉞ Carbon dioxide in the atmosphere traps solar radiation, keeping the earth warm -- the so-called "greenhouse effect." Some scientists believe that an increase in the amount of CO_2 in the atmosphere may cause an increase in temperature at the surface of the earth.

The experts concur on the possibility of a temperature increase. They disagree as to what would happen next. ㉟ If the earth becomes just a few degrees warmer, the polar ice caps could melt, raising the level of the oceans several hundred feet and flooding coastal regions. Or an increase in temperature could increase the evaporation of water from the oceans, increasing precipitation -- especially snow in the polar regions. ㊱ This could cause the polar caps to enalrge, bringing on an ice age. This reminds me of a poem by Robert Frost, entitled "Fire and Ice".

Some say the world will end in fire,

Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if I had to perish twice,
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice.

㊲ In any case, the process would take hundreds of years, and it may not happen at all. Some scientists believe that the amount of smoke and dust produced by civilization may block out enough sunlight to neutralize the effects of the increase in carbon dioxide.

One more point concerning the carbon cycle: The rates of transfer between pools may vary from one kind of ecosystem to another. ㊳ Photosynthesis fixes carbon at a rapid rate in the sunny, warm, moist climate of the tropics. In a tropical rain forest, carbon may be taken in by the plants at a rate of 4.5 kilograms of organic material per square meter of forest per year. An equal amount of organic material is broken down and recycled, mainly by the decomposers ㊴ In the tropical forest, no dead organic material is allowed to lie around for long. An abundance of insects and small soil organisms gobble up every leaf and dead ant as soon as they fall Decomposition is rapid in the warm climate. Materials are recycled so rapidly that the forest floor is relatively bare of debris

㊵ By contrast, in a typical fir forest, only 1.0 kilogram of organic material per square meter of forest may be produced each year, less than one-fourth the production of the tropical forest. About 1.0 kilogram of organic material is broken down every year. ㊶ However, a thick layer of humus covers the forest floor, and a fallen fir needle may last for several years before its carbon is recycled. Cycling of materials is slow in the fir forest, as compared to the tropical rain forest.

㊷ Organisms require 30 to 40 other chemical elements besides carbon. Some of them, like copper or cobalt, are needed in only tiny amounts, as cofactors of certain enzymes. Others, such as oxygen and phosphorous, make up large proportions of organisms and the abiotic environment and are recycled on a large scale.

㊸ Nitrogen is an important constituent of proteins. This is a diagram of the nitrogen cycle, one of the more complex material cycles. You need not memorize the diagram. It is presented merely to illustrate a cycle a bit more complicated than the carbon cycle. Pools of nitrogen are indicated by the circles; the transfer processes are shown along the arrows between the pools.

㊹ The atmospheric pool of nitrogen, in the form of N_2 gas, is huge -- making up about 80% of the mass of the earth's atmosphere. ㊺ However, only a few kinds of microorganisms are able to use N_2 gas directly, through the process of biological nitrogen fixation. Other organisms are obliged to get their nitrogen in a roundabout way from the nitrogen fixers.

㊻ The abundance of nitrogen fixers, like this blue-green alga, is quite small compared to the total mass of a typical ecosystem, but these organisms are absolutely essential to the cycling of nitrogen. A molybdenum ion is part of one of the enzymes which fix nitrogen. Thus the movement of nitrogen -- essential to proteins and life -- is linked to the presence of this rare substance. Many materials cycles are interlinked in this way.

㊼ Human technology greatly affects the nitrogen cycle. Industrial fixation of nitrogen -- making fertilizer from the nitrogen in the air -- may exceed 10 per cent of the nitrogen fixed naturally in land ecosystems. ㊽ The considerable input of nitrogen fertilizer into farm ecosystems has greatly increased world food production. If all the nitrogen put into the soil were taken up by the crops, problems would be minimal. ㊾ But some of the nitrogen is washed from the field into rivers and lakes. Richly-fertilized bodies of water often fall victim to "blooms" or population explosions of algae. When these tiny plants die, their decomposition rapidly depletes the oxygen in the water, eliminating fish and other oxygen-dependent organisms. The lake or river "dies." The near-fatal pollution of Lake Erie is probably the most familiar example.

㊿ Other major materials cycles involve the movement of sulfur, water, phosphorus, and so on. Perhaps a good way to determine whether you understand materials cycles is to see whether you can figure out a cycle. (51) If you know anything about photosynthesis and respiration, you should be able to outline the oxygen cycle of a typical ecosystem. In a moment, stop the tape and sketch the oxygen cycle. Include major pools and transfer processes. The answer is on the next slide. O.K., stop the tape.

(52) Here is a simplified diagram of the oxygen cycle. Is your sketch similar to this diagram?

This nearly completes our consideration of the movement of materials through the ecosystem. (53) In review: In a typical material cycle, the material exists in several different forms. These accumulations are called pools. The processes which convert the material from one form to another, transferring it from one pool to another, are called transfer processes. (54) Much of a cycle may be unseen, carried out by microorganisms such as decomposers and nitrogen-fixing bacteria. (55) Energy movement through the ecosystem is one-way. Input of sunlight is equalled by output of heat. Energy is not reused. (56) In contrast, materials are reused ... recycled over and over.

(57) In a way, the earth is like a huge spaceship with an unlimited supply of solar energy, but finite material resources which must not be wasted and must be used again and again. In the future, we must prevent nitrogen from accumulating in our lakes and rivers. We have to make sure that the phosphates we mine and use in fertilizers and detergents do not end up in the water, or lost at the bottom of the ocean. (58) Our limited supplies of metals will have to be recycled, rather than scattered uselessly across the landscape. Pollution consists of dead-end, unbalanced cycles. (59) Those of us with the foresight to do so should take care that our supplies of materials continue to be recycled smoothly, so that the living passengers of "Spaceship Earth" may continue their journey. (60)

MOD 208 Teaching Strategies: Questioning

Because questioning plays such an important role in the classroom atmosphere and the instructional process, especially in science, this MOD is designed to help you organize your thinking regarding the use of questioning in the classroom. It is anticipated that you will continue to refine your skills in the use of questioning throughout the remainder of your preparation program.

OBJECTIVES:

At the end of this MOD you should be able to:

1. State reasons for using questions.
2. Classify questions as to cognitive, affective, or psychomotor domains.
3. Give examples of questions for at least four levels of thinking in the cognitive domain of Bloom's taxonomy.
4. Discuss appropriate wait-time for different questions.
5. Discuss appropriate alternative ways for handling incorrect and partially-correct responses for questions.
6. Write or state examples of convergent and divergent questions.
7. Identify and/or construct questions requiring the use of a specific scientific process, i.e. hypothesizing, observing, formulating operational definitions, etc.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Carin, Arthur A. and Sund, Robert B., Developing Questioning Techniques, in Resource Center
2. Video playback equipment or film projector
3. Films or videocassettes of classrooms from SME Resource Center

PROCEDURES:

1. Read pp. 1-51 in Developing Questioning Techniques and discuss with your partner.
2. Complete questions 1-21 on pp. 17-19.
3. View a portion of a film or cassette of a classroom from the SME Resource Center and select two questions used by the teacher. Be prepared to discuss the classification and appropriateness of the questions.

FINAL ASSESSMENT:

1. Bring responses to questions 1-21 to the evaluation session and be prepared to discuss them.
2. Bring the film or cassette which you selected in Procedure 3 and present it.
3. See objectives.

MOD 209 **Relative Position and Motion (SCIS)**
Using space relationships

OBJECTIVES:

1. Given an artificial observer, "Mr. O," you will be able to describe the position or motion of a selected object in the room relative to Mr. O.
2. You will be able to describe orally the location of Mr. O. to a person unfamiliar with that location.
3. Given the activities of this MOD, you will be able to apply the following terms: reference object, relative position, relative motion.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Relative Position and Motion, Teacher's Guide
2. SCIS, Fun House, filmloop # 528-90195-8
3. 8 mm filmloop projector
4. "Mr. O" figure

FINAL ASSESSMENT:

1. When the instructor places Mr. O in a peculiar position, describe either the position of an object or the movement of that object relative to Mr. O.
2. Have the film loop ready to operate to help your discussion of answers on the attached sheets.

PROCEDURE:

1. Read the following sections in SCIS, Relative Position and Motion, Teacher's Guide:
   a. Relative Position, pp. 22-25
   b. Using Reference Objects, pp. 30-31
   c. "Inventing" Mr. O, pp. 38-43
   d. Relative Motion, pp. 48-50
   e. "Inventing" Relative Motion, pp. 52-56

2. Perform these activities:

A. Have your partner hold the Mr. O figure in various positions and try to describe how your partner sees Mr. O. Use descriptive terms such as in front of, in back of, above, below, far, near, to his right, or to his left. Then describe how Mr. O "sees" you.

B. Take Mr. O and move him in any way you desire. Discuss with your partner how Mr. O reports your change in position relative to him.

C. Have a third person select a remote hiding place for Mr. O and place him in it. Have this done in your presence, but not in the presence of your partner. Then verbally, without pointing or gesturing, try to describe Mr. O's hiding place accurately enough so that your partner can find Mr. O using only your verbal directions. When you have stated the complete directions see if your partner can find Mr. O. Do not follow or give additional help along the way. This game is analogous to someone (your partner) stopping his car to ask you how to get to a particular location (Mr. O's hiding place). Ordinarily you do not hop in the car to direct the way. You try to describe as well as you can from the uninformed stranger's point of view how to find the location.

3. Review the SCIS Fun House filmloop several times.

NOTE: When using the Super-8 filmloop projector, you can stop the film any where in the loop by pushing the silver button on top of the projector. You can injure the film if you stop the loop for too long a period of time.

Select the best answer to each question about the film. Be ready to describe your evidence. You should focus your attention on changes in relative position of the entire object or person. For example, do not be overly concerned with small parts of the object such as the girl's feet in scene 12 or the girl's hands in scene 15. Select one of these answers: no, a little, a lot.

Scene 2

1. Are the children moving relative to the slide? __________

2. Are the children moving relative to the camera? __________

Scene 6

3. Is the paper moving relative to Andy? ________________

4. Is the paper moving relative to the slide? ____________

5. Is the paper moving relative to the camera? ___________

Scene 7

6. Draw a simple sketch designating the path that the ball makes relative to the slide as the children pass the ball back and forth.

Scene 9

7. Is the barrel moving relative to the children? __________

8. Is the barrel moving relative to the camera? ____________

Scene 10

9. Is the camera moving relative to the barrel? ____________

10. Is the camera moving relative to the children? __________

11. Is the camera moving relative to the Mr. O located inside the barrel? _____

Scene 12

12. Is the girl moving relative to the camera? __________

13. Is the girl moving relative to the barrel? __________

14. Is the girl moving relative to Mr. O located inside the barrel? _________

15. Is the girl moving relative to Mr. O located outside the barrel? ________

Scene 14

16. Describe the motion of the child in the wagon as seen by Mr. O on the picket fence.

Scene 15

17. Describe the motion of the wagon relative to the camera.

Scene 17

18. Observe and draw the path that the children take relative to the striped wheel.

When you have finished using the film be sure to return the loop to the beginning of the sequence so the title reappears.

MOD 210 **Kinds of Soil**
Measuring, interpreting data

OBJECTIVES:

1. Given two different samples of soil, you will be able to separate the soil samples into seven different grain sizes as follows:
   a. larger than 4 mm.
   b. 4 mm. to 2.3 mm.
   c. 2.3 mm. to 1.2 mm.
   d. 1.2 mm. to 0.6 mm.
   e. 0.6 mm. to 0.25 mm.
   f. 0.25 mm. to 0.044 mm.
   g. smaller than 0.044 mm.
2. After separating the soil sample into various particle size lots, you will determine, on the basis of weight, what percentage of the total soil sample consists of the following:
   a. very coarse sand - larger than 1.2 mm.
   b. coarse sand - 1.2 mm. to 0.6 mm.
   c. medium sand - 0.6 mm. to 0.25 mm.
   d. fine sand - 0.25 mm. to 0.044 mm.
   e. silt and clay - smaller than 0.044 mm.
3. From the table given on page 3 of this MOD, you will determine the soil class for one of the soil samples provided.
4. After separating the soil sample into its various components, you will examine under the microscope grains smaller than 0.044 mm. and you will record your observations.
5. After separating the soil sample into its various components, you will add a small amount of water to the grains smaller than 0.044 mm. After adding enough water to moisten the sample, you will be able to describe its texture and adhesive characteristics.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Sieve set for separating a soil sample into various particle sizes
2. Two soil samples which have been heated to remove all organic material and water
3. Balances, microscopes, measures

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

General Information

Soils as seen in nature are made up of three main components. These are the mineral content, the organic content, and the water content. For the purposes of this activity, the soil samples have been heated to high temperatures in order to remove the organic and water components. When the soil is heated, the water is evaporated and the organic content is reduced to its basic molecular components such as carbon, nitrogen, hydrogen, oxygen, phosphorus, etc. These molecular components are either evaporated or are too small in particle size to be noted in the soil sample.

After the soil sample is heated, the only component that remains is the mineral content. This component, on the basis of particle size, can be characterized as consisting of sand particles, silt particles, and clay particles. By international standards, sand constitutes the coarse particles larger than 0.02 mm., and they vary in size from very samll to various larger sizes. Sand particles larger than 2 mm. are usually considered stones. "Sand particles" usually come from granite, limestone, sandstone, and shale. These represent rocks common at the earth's surface and are considered as parent materials comprising the earth's crust. Sand particles originate through a weathering process of the earth's crust which results in the formation of various sized rocks, stones, and sand. The weathering of these in turn results in the formation of a variety of soil sand particles made up of quartz, feldspar, mica, hornblende, garnet, etc. Quartz particles predominate in sandy soils.

Silt particles are generally considered to have a size range of 0.02 mm. to 0.002 mm. These are usually irregularly fragmented particles of sand in which quartz is the dominant material. If one examines silt particles under the microscope one sees that these irregularly shaped particles are usually coated with finer grains which are clay particles. One might define silt particles as fragments of sand particles that have not been weathered or polished smooth. Silt particles when further eroded or broken down to smaller particles would result in clay particles.

Clay particles are smaller than 0.002 mm. They are usually mica-shaped and when moist are highly plastic and cohesive. "Mica-shaped" means that they have a layered construction. If clay particles are wet with water they tend to swell because layers of water molecules penetrate between the layers of mineral. For this reason, they are referred to as plastic. Most clay particles exhibit a cohesiveness because they are charged with positive or negative charges and therefore are usually covered with other charged mineral elements such as calcium, iron, potassium, and sodium ions. Hence, the clay particles are very important for certain soil characteristics such as water-holding capacity and retention of nutrient ions. Although many clay particles are composed of quartz which is pure silicon dioxide, many of the quartz fragments have been chemically modified. Kaolinite, illite, and montmorillonite are common examples of clay particles that contain silicates of aluminum, sodium, iron, magnesium, and potassium. For instance, red soils have a large precentage of clay particles made up of iron silicate.

Soils are characterized by the percentages of sand, silt, and clay particles that they contain. The following table can be used to determine the class of soil:

	Class of Soil		
	Sandy Loam	Loam	Clay
A. Sand (including all particles larger than 0.044 mm)	70%	40%	23%
B. Silt and Clay (including all particles smaller than 0.044 mm)	30%	60%	77%

(Note: For this activity, because of the equipment, it will be necessary to consider 0.044 mm. rather than 0.02 mm. as the division point between sand and silt and clay.)

From the above table determine to which class of soil one of the samples belongs. For example, if the sand content is more than 70%, the sample would belong to the sand loam class. If the sand content is at least 40% but less than 70%, the sample would belong to the loam class.

Instructions

1. Weigh a 250 ml. graduated cylinder on the gram balance provided in the laboratory.

2. Fill the graduated cylinder to the 125 ml. mark with a soil sample and determine the weight of the soil by subtracting the weight of the cylinder from the weight of the cylinder and the soil.

3. Obtain the sieve set provided in the MOD tray. Note that the sieves are marked from 1 to 5 (mesh 5 to 60) and have a cover and bottom applied to the top and bottom sieves respectively. Pour the soil sample into the top sieve (mesh 5) and with the five sieves assembled shake the assembly until no more of the soil contents are falling from one sieve to another. This can be checked by periodically removing the sieves from each other and by shaking a sieve over a piece of paper. If more soil is falling through, continue with the shaking process. Be patient and shake thoroughly until the process is done.

4. After separating the soil sample into different-sized components with the sieves marked 5 to 60 mesh, pour the contents of the lowest sieve (60 mesh) into one additional sieve marked #6 (325 mesh). This sieve will allow all silt and clay particles to pass through but will hold back the fine sand.

5. You now have divided the original soil sample into seven size groups. Pour each sample on a piece of paper and measure the weight in grams. Determine the percentage each component comprises, relative to the total weight of the sample.

6. By adding up all the sand samples (percentages) and determining the percentage content of the silt and clay sample, determine the class of soil for one of the two samples of soil.

7. Fill in the chart below with the data you have obtained.

Sample used ______________

Weight of 125 ml of soil ____________ g

Components	Weight (g)	% of Total
A. larger than 4 mm	___________	___________
B. 4 mm to 2.3 mm	___________	___________
C. 2.3 mm to 1.2 mm	___________	___________
D. 1.2 mm. to 0.6 mm	___________	___________
E 0.6 mm to 0.25 mm	___________	___________
F. 0.25 mm to 0.044 mm	___________	___________
G. smaller than 0.044 mm	___________	___________

Type of Soil ______________

MOD 211 Preparation for Teaching Science to Children

PREREQUISITES: MOD 208

This MOD is designed to allow you to utilize processes, concepts, objectives, and questioning techniques you have developed in your MODs in preparing a two-period lesson for children.

OBJECTIVES:

At the completion of this MOD you and your partner should present a completed, neat, two-period plan for a MOD for elementary children at the level (primary or intermediate) that you wish to teach. The plan should include:

Title
Processes and/or concepts
Grade level
Overview
Objectives
Materials and equipment
Outline of procedures
Key questions
Assignment (if any)
Final assessment

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Materials and equipment in SME Resource Center
2. References, including elementary texts, in SME Resource Center
3. SAPA, Commentary for Teachers, pp. 19-24 in newer edition and pp. 21-26 in older edition
4. Carin, Authur A. and Sund, Robert B., Developing Questioning Techniques

PROCEDURES:

1. Prepare a rough draft of a plan for 8-10 students utilizing what you have learned in your ISMEP MODs at the level you wish to teach (check with instructor for the specific grade).
2. Discuss plan with an instructor incorporating any changes agreed upon.
3. Prepare a final copy of your plan in neat form, preferably typed.
4. Assemble the materials needed to teach the MOD to 8-10 elementary children.
5. Schedule a session with an instructor to review the final plan.
6. Prepare a copy of the plan to submit to the classroom teacher.

FINAL ASSESSMENT:

1. Assemble materials and a good copy of your plan.
2. Be prepared to defend your objectives, questions, assignment, and assessment plan.
3. Present a copy of your plan, with handouts where appropriate, for the teacher in whose classroom you will teach the lesson.

MOD 212 Energy Sources (SCIS)
Controlling variables

PREREQUISITE: Read SCIS, Energy Sources, Teacher's Guide, pp. 22-24 to review the concepts of (1) objects and their properties, (2) interaction, (3) system, (4) subsystem.

OBJECTIVES:

1. Given the apparatus in the MOD tray and sufficient time to experiment, you will be able to shoot a rubber stopper out of a syringe accurately enough to hit a 2-foot diameter circle fifteen feet away at a minimum score of 7 out of 10 hits.
2. You will be able to identify the important variables that influence the flight distance of a stopper shot from a syringe.
3. You will answer the questions on the attached sheets as related to the exercises.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Energy Sources, Teacher's Guide, pp. 22-25
2. "Stopper-popper," tape measure, protractor

FINAL ASSESSMENT:

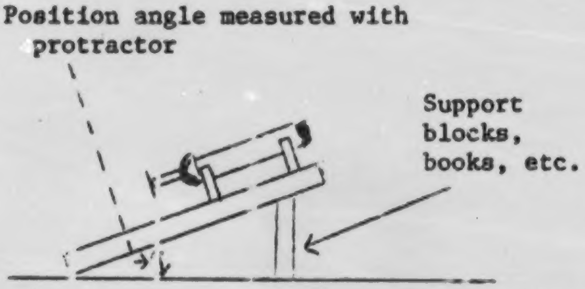
See objectives above.

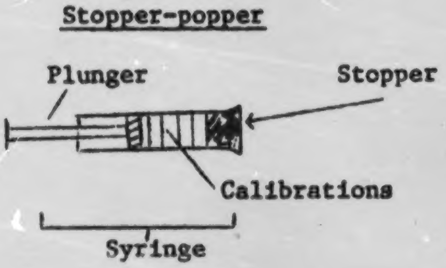
PROCEDURE:

In the MOD tray find the syringe with a rubber stopper-the stopper-popper. Jam the stopper into the open end of the syringe and "fire" the stopper by pushing in on the plunger. As you practice working the stopper-popper, you should get a feeling for how to increase the flight distance. List these factors.

Also in the MOD tray is the stopper-popper support system of notched wood and a platform. By setting the stopper-popper into the notches and raising one end of the support, you can control the trajectory of flight. Practice with this system until you get a feeling for the height of stopper vs. the angle of trajectory.

With chalk draw a circle with a 2-ft. diameter on the floor to serve as a target for the stopper. Fifteen feet from the center of this circle draw a line to serve as the position of the platform. The objective of the following exercise is to determine the position angle of the platform and other factors such as the force of plunger necessary to hit the 2-ft. circle 7 out of 10 tries. See diagrams below.


Position angle measured with protractor
Support blocks, books, etc.



Use the following format to record your ten trials on the back of this page.

	Angle	Force units on syringe
Trial #1	10°	
Trial #2		

Answer the following items:

1. What evidence is available that energy has been transferred?

2. Trace the energy of the moving stopper back to the energy source, the sun. Use the back of this sheet if you need more space.

3. Describe the conditions under which the stopper flew the longest distance.

4. How does the position angle of the stopper-popper affect the flight distance of the stopper?

5. Does the rate of descent of the plunger affect flight distance?

6. What happens to the energy of the flying stopper to cause it to come to rest?

7. How does the depth of the stopper in the syringe affect flight distance?

8. How does the amount of air in the syringe before the stopper is plugged affect flight distance.

MOD 213 Water-Holding Capacity of Soil
Measuring, interpreting data

OBJECTIVES:

1. Given three kinds of soil, silty clay, loam, and sandy loam, you will measure and compare the weights of equal volumes of the different kinds of soil.
2. Using equal volumes of each of the soils, you will determine the relative water-holding capacities (field capacities) of the soils.
3. Using soil samples saturated to the water-holding capacity, you will determine the actual weight of water per gram of soil.
4. From the data collected in this activity, you will formulate an inference explaining the different water-holding capacities of the soil samples used.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Smith, Ecology and Field Biology, pp. 212-221
2. Soil samples, glass tubes, Saran Wrap, rubber bands glassware, clamps ring stands, balance

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

Before doing the activity, it is necessary that you are able to define the following terms:

1. field capacity - the total amount of water that is held by a soil against the force of gravity and the downward pull of capillarity and that does not drain through the soil
2. hygroscopic water of soils - the relatively small amount of water absorbed by dry soil from the atmosphere
3. capillary water of soils - amounts of water retained in minute spaces between fine soil particles, and as films surrounding soil particles, and by absorption by soil colloids
4. gravitational water of soils - after a heavy rain or irrigation, much of the water drains or sinks away; this is called gravitational water

Soil Characteristics

Excepting humus or decaying organic materials, all soils are basically composed of the same minerals. Most soils consist of primary minerals that are composed of silicon in combination with other elements. These may include silicon in combination with oxygen, aluminum, calcium, sodium, magnesium, and iron. Other soils may be composed of silicon compounds mixed with variable amounts of calcium carbonate and calcium phosphate.

Another characteristic of soils is the size of the constituent mineral particles or crystals. Sand, for instance, is composed of a high percentage of silicon dioxide particles that are 0.02 mm. in diameter or larger. Soils are characterized by the proportion of the soil made up of a certain particle size. The table below shows the particle size characteristics of the three soils used in this activity.

	Percentage of Each Type of Particle		
	Sandy Loam	Loam	Clay
Fine Sand to Coarse Sand	47.1	26.5	6.7
Very Fine Sand	22.0	13.2	16.8
Silt Particles	21.1	43.2	28.0
Clay	9.8	17.1	48.5

Particle Size for the Various Categories:

Coarse Sand to Fine Sand	2.00 to 0.10 mm
Very Fine Sand	0.10 to 0.02 mm
Silt	0.02 to 0.002 mm
Clay	below 0.002 mm

1. Determination of weight-volume relationships

   A. Weigh a 00 ml. graduated cylinder to the nearest gram on the balance provided.
   B. Fill the cylinder to the 250 ml. mark, and gently tap the bottom of the cylinder with the palm of your hand to settle the soil uniformly.
   C. Weigh the cylinder and the soil to the nearest gram.
   D. Determine the weight of 250 ml. of each kind of soil. Using the heaviest soil as a reference (100%), determine the relative weights of the other two samples (in percents).

	Type of Soil		
	Sandy Loam	Loam	Silty Clay
Weight of 250 ml.			
Relative Weights in Per Cent			

2. Determination of relative water-holding capacity (field capacity) of each soil

   A. Obtain 3 glass tubes from the MOD tray. Using a rubber band, close one end of the glass tube with a square of cloth found in the MOD tray. Weigh the tube to the nearest gram.
   B. Measure 250 ml. of soil into each of the tubes, using one kind of soil for each tube. Gently tap the bottom of the tube with the palm of your hand to evenly settle the soil. Weigh the tube and soil to the nearest gram. The total weight minus the weight of the tube will give you the weight of the soil sample.
   C. Assemble a support stand with two clamps, and clamp the glass tube to the support.
   D. Place a 400 ml. beaker under the tube and add 250 ml. of water to the top of the tube. Cover the top of the tube with aluminum foil.
   E. Allow the tube to stand for 24 hours or until no more water is draining from the tube into the beaker.
   F. Weigh the tubes and soil.
   G. Calculate the weight of the soil sample with its water.
   H. Calculate the weight of water retained by the soil.

	Type of Soil		
	Sandy Loam	Loam	Silty Clay
Grams of Water Retained			
Grams of Water Retained per Gram of Soil			

Note: The soils used in this activity were dried at 100°C. before they were set out for you. All increase in weight at field capacity was due to water-holding capacity.

MOD 214 Basic Probability and Its Role in the Elementary School

This MOD is concerned with the basic concepts of probability.

OBJECTIVES:

At the completion of this MOD you will be able to:

1. Use games to explain probability.
2. Give a quantitative meaning to the idea of uncertainty.
3. Determine the set of possible outcomes for a given situation.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Probability and Statistics
2. MMP slide-tape, "Overview of Probability and Statistics"
3. 25 chips of four colors, spinner with 3 colored sectors, coin, 2 die, deck of bridge cards, several circular cylinders

PROCEDURE:

1. View the MMP slide-tape "Overview of Probability and Statistics."
2. In MMP, Probability and Statistics, do
   Activities 1: Parts I, II, and the General Question
   2: Parts 1, 2, 3, 4, and 7
   3: Parts 1, 2, 3, 4, and 5b
3. Prepare a game for your file on probability.

FINAL ASSESSMENT:

1. Bring all work sheets and your game to the evaluation.
2. Be able to answer questions relative to the objectives.

MOD 215 Models: Electric and Magnetic Interaction (SCIS) Communicating, controlling variables

OBJECTIVES:

1. Given a source of electrical current, compasses, and some wire, you will demonstrate that a magnetic field accompanies an electrical current.
2. Given a source of electrical current, a large nail or rivet, compasses, and some wire, you will construct an electromagnet.
3. Given a coil of wire, a bar magnet, and a galvanometer, you will demonstrate that a changing magnetic field induces electrical current in the wire.
4. Given the materials in the MOD tray, you will construct a scientific model for electricity.
5. You will select a natural system other than the ones encountered in this MOD, and construct a scientific model that enables you to make predictions about the behavior of the system.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Models: Electric and Magnetic Interactions, Teacher's Guide
2. Flashlight batteries, power pack, insulated wire, compasses, iron filings, galvanometer, bar magnet, large nail or rivet, small light bulb, brass clips

FINAL ASSESSMENT:

1. See the objectives above.
2. Be prepared to discuss your written records with the instructor.

PROCEDURE:

Note: A power pack may be used in place of batteries in activities 2, 3, and 5.

1. These activities refer to chapters in SCIS, Models: Electric and Magnetic Interactions, Teacher's Guide. Read the following pages as preparation:
   "Models," pp. 44-47
   "Devising Models," pp. 56-59
   "A Magnetic Field Model," pp. 60-65
   "An Electricity Model," pp. 82-83

2. Connect a wire to one terminal of a battery. Let the wire pass over a small compass so that the wire and compass needle are aligned and momentarily touch the loose end of the wire to the other terminal of the battery. Note what happens to the compass. Place the wire under the compass and repeat the procedure. What does the behavior of the compass imply about the space surrounding the current-bearing wire? Refer to the diagram in the SCIS Teacher's Guide, p. 65.

3. Wrap a wire many times around a large nail or rivet. Connect the two ends of the wire to one or more batteries. Investigate the effect of the nail or rivet on compasses, iron filings, and small iron objects that you locate around the room. Do not allow the current to flow for periods much longer than 30 seconds or the batteries will wear down very quickly. Make variations in the number of turns of wire, strength of current source, or connection of terminals. Note their effects.

4. **CAUTION:**
Do not connect the galvanometer to the batteries or any other source of current!
Take a bar magnet from the MOD tray. Form a wire coil of many turns which will fit around the magnet. Connect the two ends of the wire to a galvanometer which is a delicate meter that detects the presence of electric current. Move the bar magnet into and out of the coil. Note the needle on the meter. Change magnetic poles and see what happens. Connect the ends of the wire to opposite terminals on the meter. Watch the needle very closely as its movement is slight and transitory. How is this interaction between electricity and magnetism different from the interaction between the battery and the compass in activity 2?

5. **Review "An Electricity Model," pp. 82-97. Given the materials in the MOD tray, set up an electrical system. Then construct a model for electricity based upon that system. MOD** 176 is closely related to this activity. If you completed it last term that experience should be helpful. In the space below, use a diagram to help communicate your model for electricity, but also explain it in writing.

6. Select any natural system you wish other than ones referred to in this MOD. Construct for the system a model that will enable you to make predictions about the behavior of the system. Discuss your system below.

MOD 216 Environmental Plot Analysis
Classifying, measuring

OBJECTIVES:

1. After completing a "line intercept technique" for studying plant forms in a plot, you will be able:
    - a. to determine the relative density of each species found in the plot area;
    - b. to determine the dominance or cover per cent of ground surface of the plot area;
    - c. to determine the relative frequency of each species seen in the plot area.
2. After separating the plant specimens seen in the line transect, you will further classify these plants into the major plant categories described in the REFERENCE SHEETS FOR MOD 216.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Reference Sheets for MOD 216 in the MOD
2. This MOD, pp. 2-3
3. Smith, Ecology and Field Biology, 2nd ed., pp. 695-696
4. Native vegetative area
5. 12-foot tape measure, transect line, and supporting rods to be obtained from the lab attendant

FINAL ASSESSMENT:

See objectives above. Be ready to present your data to the instructor in an organized form.

All living organisms can be ordered or classified on the basis of their structure In classifying organisms one can begin with the simplest forms and end with the more complicated forms. If all organisms are composed of a basic unit, the cell, then it follows that the simplest living forms would be those that consist of only one such unit, that is, single-celled organisms. Because nature can make many different kinds of cells, there may be many different kinds of single-celled organisms. The bacteria, algae, amoebae, and euglena are typical examples of single-celled organisms.

Some organisms are composed of clusters or associations of cells. If all the cells in the cluster are of the same kind, of the same shape and form, the organism is called a colonial multicellular organism. In these organisms none of the cells are specialized for a specific function but all can carry on all the life functions for nutrition, growth, and reproduction.

A next step toward higher complexity is the formation of organisms composed of aggregates of several kinds of cells. Usually in these organisms each specific group of cells is specialized to perform a unique function. For example, nerve cells for coordination of the whole, cells forming pathways for circulation of substances throughout the whole, cells adapted for collecting food and digesting food for the whole organism, etc. In these organisms a tissue level is reached, and each group of a particular kind - particular in shape, form, and function - is called a tissue.

An additional step to higher complexity is the organ level. In this level several tissues in one part of the body may work together for a common purpose. The lungs are composed of several tissues and function to supply oxygen to the whole organism. The kidney is another example and has the function of removing waste products from the whole organism.

A final step to a rise in complexity is the system level. In this level several organs work together for a function in the organism. The heart, blood, blood vessels, and some glands all coordinate to produce an effective circulation system.

Plants and animals have not reached the same levels of complexity. Plants have evolved to the tissue level with possibly some development toward the organ level. Animals have representatives at all levels of complexity from single-celled organisms to organisms at the system level.

1. In this MOD you will be concerned with a variety of plant forms. Animals are considered separtely . A general description of the seven major plant forms and some of their subgroups is given below.

A. Plants not having vascular bundles.

Group I. Algae	Single-celled and colonial forms possessing chlorophyll. No true tissue.
Group II. Fungi	Colonial forms, not possessing true tissue. Non-green plant-like forms. (molds, toadstools, mushrooms, mildews)
Group III. Liverworts	Green plants having leaves only. No stems or roots, leaves growing prostrate on the ground or rocks.
Group IV. Mosses	Small green plants having leaves only. Appearing as small leaves clusterd together to form a "stem." Do not form seeds.

B. Plants having vascular bundles.

Group V. Ferns	Plants having leaves and stems. Stems always under the ground with leaves only visible above ground. Do not form seeds.
Group VI. Evergreens or Conifers	Plants having leaves, stems, and roots. Leaves most often needle-like. Produce seeds, have cones instead of flowers. (pines, firs, spruces, hemlocks, cycads, ginkgos)
Group VII. Deciduous Plants	Plants that lose their leaves once a year and become dormant. Produce seeds from flowers.
Subgroup: Monocotyledons	Produce seeds having only one cotyledon. Petals and sepals of flower in three or multiples of three. Vascular bundles scatter in stem. Narrow leaves with parallel veins. (grasses, palms, irises, bananas, tulips, orchids, corn)
Subgroup: Dicotyledons	Produce seeds having two cotyledons. Petals and sepals of flowers in groups of five or multiples of five. Vascular bundles ring-like in stem, broad leaves and veins branching. (trees, shrubs, herbs)

PROCEDURE:

It is important that you select an environmental plot that will not be too difficult to analyze and one that will have a variety of kinds of plants. A "lawn" type of plot will not be satisfactory because the growth of grass plants will be so dense that it will be impossible to count the individual plants. You should select a plot where there are several kinds of plants and where the plant density is such that bare ground areas are exposed. Where can you find such a plot? You might try next door by Bee Creek or in an area where the tree growth is not too dense and where undergrowth of grasses, herbs, mosses, etc. is permitted. Get Dr. Wolfson's permission before using area next door.

You should not be concerned with specific identification of individual plant species. The different species or kinds of plants may be designated as species 1, species 2, etc. In completing objective 4, you should classify the plant species according to the classification system learned in MOD 132.

Follow the procedures below.

1. Find an environmental plot you consider satisfactory.

2. Suspend the 12-foot tape measure between the stakes provided.

3. The tape measure is divided into twelve 1-foot intervals which are further divided into inches. While standing directly over the tape measure, determine the areas of the transect that do not have plant cover. This is the same as designating which areas directly below the tape are seen as dirt, dead leaves, etc. For example, the information may be recorded on the chart as "Interval 3, 2-6 inches" (portion of the tape from 3 feet, 2 inches to 3 feet, 6 inches).

4. While you look down over the tape, count all plants that you see occupying space under the tape. This may include plants whose roots are anchored in soil to the side of the tape but have parts extending under the tape.

5. In counting the plants you should identify them according to species number. For example, your data may appear as "Interval 3, 1 of species #1, 5 of species #3, and 2 of species #6."

6. Complete the above counts for the three 12-foot transect lines.

7. Analyze your data to determine relative density, dominance or cover per cent, and relative frequency by using the following formulas.

$$\text{Relative density} = \frac{\text{total individuals of a species}}{\text{total individuals of all species}} \times 100$$

$$\text{Dominance or cover per cent} = \frac{\text{total distance in inches of transect line covered by plants}}{144} \times 100$$

$$\text{Frequency} = \frac{\text{intervals in which a species occurs}}{12} \times 100$$

$$\text{Relative frequence} = \frac{\text{frequency value of a species}}{\text{total of all frequency values of all species}} \times 100$$

Species	Interval*											
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Ground Exposure (in inches)												

*One Interval = 12 inches

MOD 217 Problem Solving I

This MOD will provide opportunities for solving problems and identifying some useful methods in problem-solving.

OBJECTIVES:

At the conclusion of this MOD you sill be able to:
1. Find methods for getting started with a plan to solve a problem.
2. Adapt problem-solving strategies to particular problems.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Problem Solving
2. Handouts for Strategy I, II, III
3. Grid paper, 1 x 2 tiles, blocks, ruler

PROCEDURE:

1. Read "Introduction" and "Perspective" sections in MMP, Experiences in Problem Solving.
2. Do Activities 1, 2, and 3.

FINAL ASSESSMENT:

1. Bring all work sheets to the evaluation.
2. Be able to answer all questions relative to the objectives.

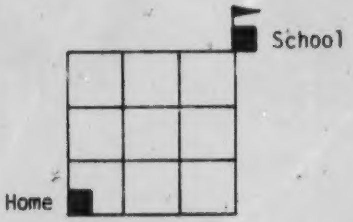
HANDOUT FOR STRATEGY 1

Understand
Plan
Carry out
Think back

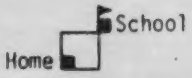
When you are faced with a problem whose solution is not immediately obvious, it is frequently helpful to begin by studying a simpler but related problem. This is our STRATEGY 1 and we refer to it as simplification. In this handout we will show how it can be useful in the "Riding to School" problem of Activity 1. Simplification may lead to an idea of how to solve the problem or how to best view the problem. Solving a simpler problem may actually provide an answer which can be used in the solution of the original problem, or a method which solves the simpler problem and which also leads to a solution of the original problem.

Simplifications of the "Riding to School" problem.

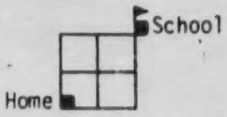
We use the "Riding to School" problem to illustrate the strategy of simplification. The problem is posed in Activity 1 in terms of a 3 x 3 block grid:



There are some obvious candidates for simpler problems which might be considered.



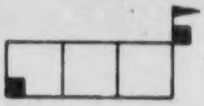
a one-block problem



a 2x2 block problem

Both of these problems possess a certain symmetry which, as we shall see, is quite useful.

Another type of simpler problem which does not have this symmetry is a 1 x 3 block problem:



There are of course other candidates, but these examples are sufficient to indicate what we mean by a simpler problem.

Throughout the discussion which follows we adopt a "north" and "east" terminology which reflects the customary identification of north with the upward direction ↑ and east with the right-hand direction →.

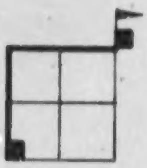
An analysis of some simpler but related problems

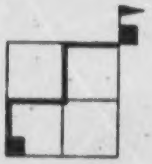
Understand
Plan
Carry out
Think back

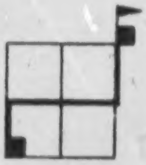
We begin with an analysis of the one-block problem. There are clearly two different (direct) paths to school:

NE (first north and then east); and
EN (first east and then north).

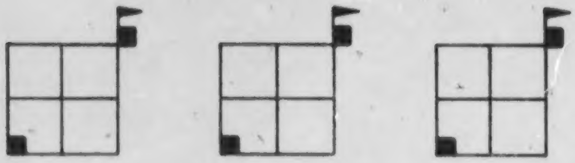
The situation is slightly more complex in the 2 x 2 block problem. If we adopt the (implicit) assumption that only the most direct routes are of interest, then each path to school is four blocks long. Three of the possible routes are







Notice that each of these routes begins by heading north. There are also three routes which begin by heading east. Draw them on the figures on the following page.



Since a route must begin either by heading north or east, and since we have identified all of the routes in either case (why?), it follows that there are six routes from home to school in the 2 x 2 block problem.

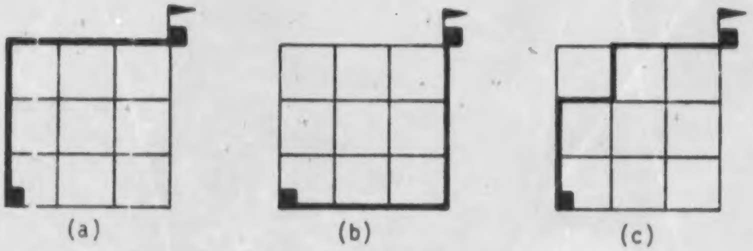
The answer to the 2 x 2 block problem (six routes) and the method of obtaining the answer (use the symmetry of the grid to divide the problem into two parts: count the routes which begin by heading north and those which begin by heading east) will be used to attack the 3 x 3 block problem of Activity 1.

Understand
Plan
Carry out
Think back

Back to the original problem

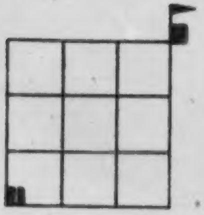
Let us begin by simply drawing some of the routes Sally can travel from home to school. Three routes are shown; find three more.

Understand
Plan
Carry out
Think back

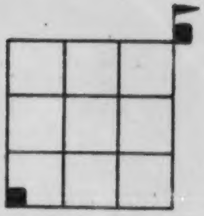


(a) (b) (c)

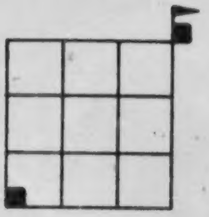
Three of the routes...



(d)



(e)



(f)

You provide three more...

It should be clear that each (direct) route from Sally's house to the school must be six blocks long. She has to go a total of three blocks to the north and three blocks to the east.

Let us use the method developed in our study of the 2 x 2 block problem to attack the 3 x 3 block situation. This method, which exploits the symmetry of a square grid, can be used to show that for every route which begins by heading north (as in (a)) there is one which begins by heading east (as in (b)). One way of making this clear is the following. If the routes are labelled by the directions taken at each corner, N or E, then route (a) can be labelled NNNEEE and (b) can be labelled EEENNN. The directions N and E are simply interchanged in these two routes! The route shown in (c) can be labelled NNENEE. What are the labels for the routes you provided in (d), (e), and (f)?

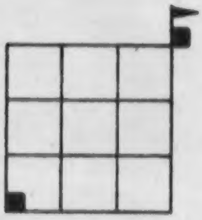
– – – – – – (d)

– – – – – – (e)

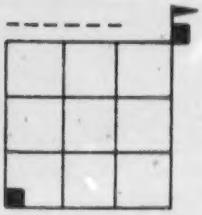
– – – – – – (f)

Notice that since each route is six blocks long, each label consists of six letters: three N's and three E's.

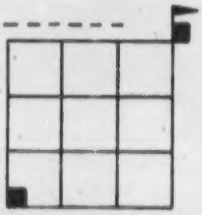
What is the route that results from interchanging N and E in (c)? Find the label and draw the path.



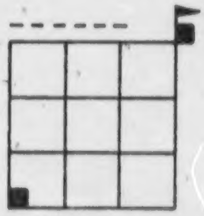
Use this technique to find the symmetric routes (those resulting from the interchanged N and E) to those you constructed in (d), (e) and (f) on the previous page.



symmetric to (d)



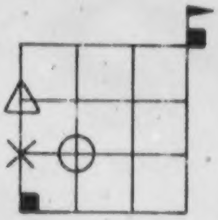
symmetric to (e)



symmetric to (f)

In summary, to every route which begins by heading north, there corresponds another which begins by heading east, namely the route whose label is obtained from the label of the first by interchanging N and E. Therefore, the complete set of routes can be written as a set of symmetric pairs (e.g., NNNEEE and EEENNN) and consequently, the total number of routes is twice the number of routes which begin by heading north. We have used the symmetry of the grid to reduce the problem to one of finding the number of routes from Sally's house to the school which begin by heading north; the answer to the original problem is twice this number. In making this reduction we have used the method we discovered in studying the 2 x 2 block problem.

Our next problem is to count the number of routes which begin by heading north. Each such route must pass through the corner marked × in the diagram below.



At the corner × a decision must be made: either go north or go east. If the route heads east from corner × then the next corner it reaches is the one marked ○ ; if it heads north then the next corner it reaches is the one marked △. Thus, again the problem is reduced to simpler ones:

A: Find the number of routes from corner ○ to school, and

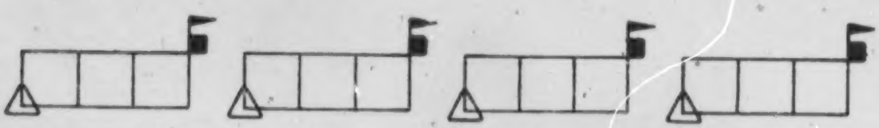
B: Find the number of routes from corner △ to school.

This is a good place to pause for a moment to be sure that you see how to answer the original question once you know the answers to these two questions.

We shall see that we can use the answers to some simpler problems to answer A and B. We consider each one separately.

A: The problem of determining the number of routes from the corner marked ○ to the school is just the 2 x 2 block problem we solved above! We use the answer, six, to conclude that there are six routes from Sally's house to the school which begin by heading north and which go through the corner marked ○.

B: This is another type of simpler problem, and it is essentially the 1 x 3 block problem introduced near the beginning of this handout. Explain why there are exactly four direct routes from corner △ to the school. (Hint: Sally must go one block further north from △. On how many streets can she ride this block?) Draw the four routes from corner △ to the school on the figures below.



Why is it impossible to use a symmetry argument analogous to the one used earlier to find the total number of routes from △ to the school?

We conclude that there are four routes from Sally's house to the school which begin by heading north and go through the corner marked △. Notice that in solving these simpler problems we used answers obtained above.

A solution of the original problem

Since there are six routes from Sally's house to the school which begin by heading north and go through the corner ○ and four routes which begin by heading north and go through the corner △, there are 6 + 4 or 10 routes from Sally's house to the school which begin by heading north. Referring to the discussion of symmetry, we conclude that there must be 10 routes which begin by heading east. Thus there must be 20 different routes from Sally's house to the school.

Those of you who solved the problem on your own may feel that we have gone to great lengths to explain things which are obvious. You may be right, and this is an example of an argument which is easy once you see it but lengthy to explain in detail. However, we feel that it is worthwhile to provide all the details at least once. Subsequent handouts will provide less and require more of you.

When and how to use STRATEGY 1

How can one tell whether the "simplification" strategy will be useful on a specific problem? There are no hard and fast rules, but the following examples illustrate the types of problems on which it is natural to try simplification.

1. Given a problem involving an $n \times n$ array of some sort, consider an analogous problem with a smaller array. The "Riding to School" problem of this activity is an example of this type.

2. Given a problem involving n quantities of some sort, consider an analogous problem with fewer quantities.

3. Given a problem involving an arbitrary triangle, consider first the case of an isosceles or equilateral or right triangle.

4. Given a problem in three (or two) dimensions, i.e., in a space, consider an analogous problem in two (or one) dimensions, i.e., in a plane. For example, Euler's formula for three-dimensional polyhedra can be obtained by examining planar graphs.* This idea will be used in Activity 2.

Concluding Remarks

Understand
Plan
Carry out
Think back

It is suggested that you try to analyze each problem you work in Activity 1 along the lines illustrated in this handout. You will be asked to prepare such an analysis as a part of Activity 5. It is worthwhile to develop the habit of reflecting on which methods were successful and which unsuccessful for each problem. In this way you develop a set of experiences on which you can draw in future problem-solving activities.

Finally, it should be mentioned that in some cases the simpler related problem may not actually be simpler to solve but is merely simpler for you since you already know how to solve it. For example,

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*See the *Awareness Geometry* unit of the Mathematics-Methods Program for some work on Euler's formula in the plane.

a geometry problem involving the proportional sides of two triangles may be related to a result you know involving similar triangles. The latter result may be useful in solving the original problem, but it may be as complex (or perhaps more complex) than that problem.

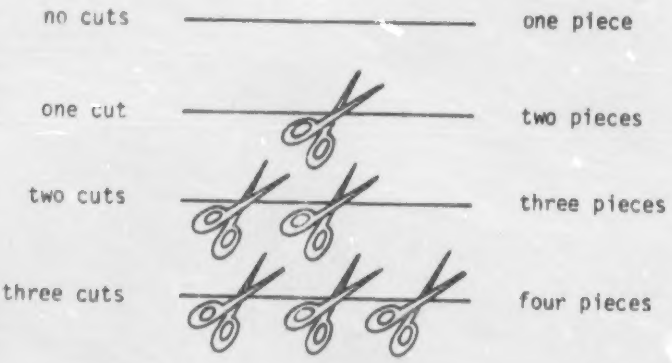
HANDOUT FOR STRATEGY 2

The first problem of Activity 2 provides an example of a problem in which a certain regularity in a sequence of numbers, a number pattern, leads to a solution. We begin our study of the problem with a simplification and the identification of a number pattern in the simpler problem. We continue with a detailed study of the original problem with fewer than six cuts. A table of numbers will be constructed and a formula conjectured. Strategy 2, which is exemplified by the identification of number patterns and formulas relating quantities of interest, will be referred to as the strategy of finding a number pattern and formula.

Solving a simpler problem using a number pattern and formula strategy

Understand
Plan
Carry out
Think back

The hint provides a useful suggestion for getting started on the problem. If we view the piece of string as a line segment, then one cut divides the string into two pieces, two cuts divide it into three pieces, and so on. The situation can be pictured as



If we introduce the notation S(n) to denote the number of pieces resulting from n cuts, then the information contained in this diagram can be summarized in a table:

number of cuts (= n)	0	1	2	3	...
number of pieces (= S(n))	1	2	3	4	...

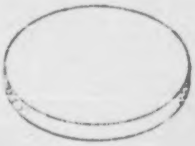
Based on the evidence presented in this table it is reasonable to conjecture that in general n cuts will produce n + 1 pieces of string, i.e., that S(n) = n + 1.

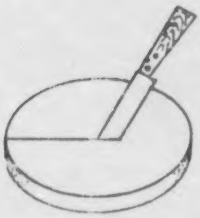
Back to the original problem

Having seen how to observe a number pattern and generate a formula we turn now to the original problem, i.e., the potato-dicing problem, and we attack it using the method we applied to our study of the simpler problem. To that end we begin to construct a table similar to the one constructed for the string problem.

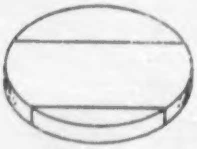
Understand
Plan
Carry out
Think back

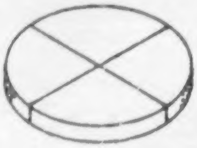
If we make no cuts in the potato, then we clearly have one piece. If one cut is made, then two pieces result.





However, at the next step (i.e., two cuts) a complication arises which did not arise in the string problem. The complication is that two cuts can be made in two, quite different, ways:


(a)

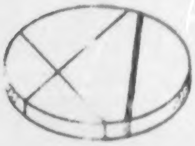

(b)

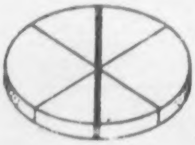
Since the problem for us is to determine the greatest number of pieces which can be obtained by slicing a disc with a specified number of cuts, the cuts shown in figure (b) are the desired ones. Indeed, the two cuts shown in figure (a) yield three pieces whereas the two cuts shown in figure (b) yield four pieces. Let us begin to construct a table with the information obtained so far. In the table we let "n" denote the number of cuts and "P(n)" the greatest number of pieces which can be obtained with n cuts. (Is the use of the function notation P(n) appropriate? Why?)

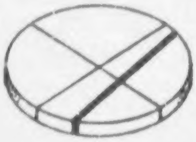
Using the information generated by considering none, one, and two cuts we have the table

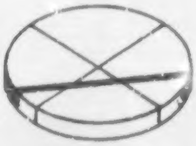
n	0	1	2	3	4
P(n)	1	2	4		

To continue, we assume that to obtain the greatest number of pieces with three cuts, the first two cuts ought to made as in figure (b) above, and then a third cut added. How should the third cut be made? There are the following possibilities (the third cut is indicated by a bold line).


(c)


(d)


(e)


(f)

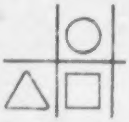
If the third cut is made as shown in figure (c) then five pieces result; if it is made as in figures (d) or (e) then six pieces result; and if it is made as in figure (f) then seven pieces result. We conclude that in order to obtain the maximum number of pieces, then the third cut should be made as in figure (f) and P(3) = 7. Adding this information to our table we have

n	0	1	2	3	4
P(n)	1	2	4	7	

We have now reached a point at which the central idea in Strategy 2 can be applied: we look for a pattern in the table of data obtained from the special cases of 0, 1, 2, and 3 cuts.

A CONJECTURE

Looking for a number pattern in this table we observe that 1 + 1 = 2, 2 + 2 = 4, 4 + 3 = 7; that is, in each case in the table whenever three numbers △ , ○ and □ are located as shown



Then we have

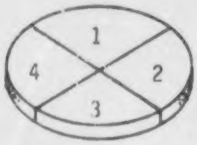
$$\triangle + \bigcirc = \square .$$

It is a bit risky to make a conjecture, i.e., a guess as to a general result, using such scanty data; and we will extend the table one more step and check whether our observation continues to hold. In fact, we will proceed in such a way as to show why the observation must hold.

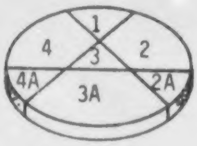
Understand
Plan
Carry out
Think back

This procedure of guessing a pattern on the basis of experience and then attempting to verify the pattern is part of the process of thinking back.

We proceed to provide support for our conjecture, and we do so by examining the cutting process in detail to determine how new pieces are created. Let us examine the addition of a third cut. The three new pieces (2A, 3A, 4A) can be viewed as parts of old pieces. Since each old piece can be divided into at most two pieces by a new cut, the most desirable way of making a new cut is to have it go through as many old pieces as possible. Thus, in slicing the disc shown in (b) with a new cut, we might hope to cut through each of the four old pieces and obtain a total of eight pieces. However, this is too much to expect, and it is impossible for a new cut to go through all four old pieces. The difficulty is that the new cut can cross each of the old cuts at most once. Therefore, if a new cut crosses both portions of the old cuts bounding the piece labelled 3 in figure (b), then it cannot also cross the portions of the old cuts which bound the piece labelled 1. The best possible new cut can be viewed as follows:



(b)



(f)

- It first cuts through the piece labelled 2 and creates a new piece 2A.
- It then crosses an old cut and creates a new piece 3A by dividing the old piece 3.
- It then crosses the remaining old cut and creates a new piece 4A by dividing the old piece 4.

That is, the new cut creates a new piece (2A) upon its entry into the potato and an additional new piece for each old cut it crosses, a total of three new pieces. One way to think of this is that

$$P(3) = \underbrace{P(2)}_{\boxed{\text{pieces from two cuts}}} + \underbrace{3}_{\boxed{\text{new pieces from third cut}}} = 4 + 3.$$

This supports the conjecture made on page ST2-4.

Let us continue the argument one more step and consider four cuts. Again, let us begin with the best possible set of three cuts and add a new cut. The new cut will create a new piece initially and an additional new piece for each old cut it crosses. It can cross at most three old cuts (that is all there are), and therefore at most four new pieces can be created. If four new pieces can be created, then using our notation this can be expressed as $P(4) = P(3) + 4$. Since $P(3) = 7$ we conclude that $P(4) = 7 + 4 = 11$. The table can be expanded and we have

n	0	1	2	3	4
P(n)	1	2	4	7	11

In fact, one can position four cuts so as to achieve 11 pieces. Try to do so.

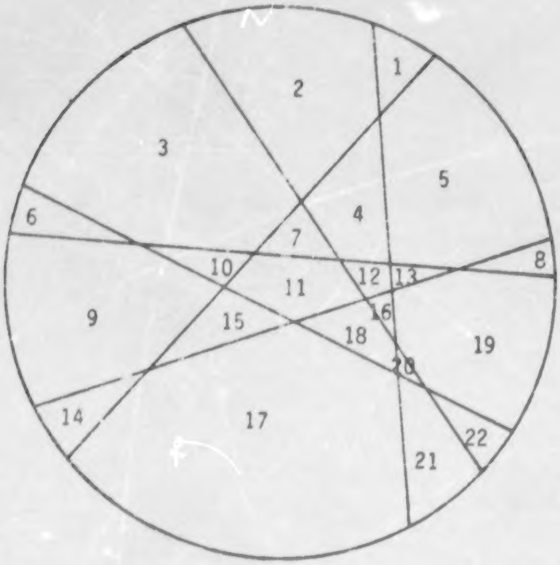
We can finish up the original problem by using the conjecture as if it were established fact. (Indeed, one can "prove" or "demonstrate" that the conjecture is a true statement by a logical argument.) The conjecture leads to the conclusion that with five cuts we have

$$P(5) = P(4) + 5 = 11 + 5 = 16,$$

and finally with six cuts,

$$P(6) = P(5) + 6 = 16 + 6 = 22.$$

A figure which shows that P(6) is at least 22 is given below. It can be shown that P(6) is exactly 22.



A mathematical footnote

The conjecture that for each three numbers △, ○ and □ situated as $\begin{array}{c|c|} & \bigcirc \\ \hline \triangle & \square \end{array}$ in the table we have △ + ○ = □

can be formulated more precisely as

$$P(n) + (n + 1) = P(n + 1) \quad \text{for} \quad n = 0, 1, 2, \ldots$$

Verify this for the table with $n = 0, 1, \ldots, 6$.

n	0	1	2	3	4	5	6
P(n)	1	2	4	7	11	16	22

Can you find a formula for P(n) in terms of n? (Hint: It may be helpful to use the relation $P(n) = n + P(n - 1)$.)

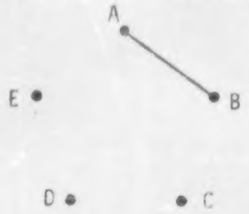
HANDOUT FOR STRATEGY 3

This is an example of a problem in which it is helpful to decompose the original problem into a number of special cases. This method of attack, that is, the separation of a problem into a number of subproblems or special cases, is our Strategy 3. In this instance the criterion which is used to decompose the original problem into special cases is fairly obvious, namely, the number of straight line segments. Each special case is studied separately, and the solutions of all cases are then combined to give a solution of the original problem. In this example, as often happens, either the results of the study of one special case or the methods developed to study that case, or both, are helpful in the other cases. In the future we will refer to this approach as the strategy of attacking special cases.

In the discussion of problem 1 of Activity 3 which follows we refer to a straight line segment connecting two dots as a connection. The introduction of terminology of this sort frequently facilitates the communication of ideas and may substantially shorten the problem-solving process. Following the proposed decomposition of the original problem we consider several cases, each corresponding to a fixed number of connections.

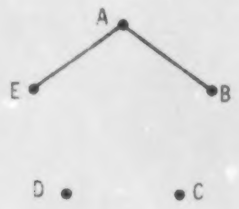
Understand
Plan
Carry out
Think back

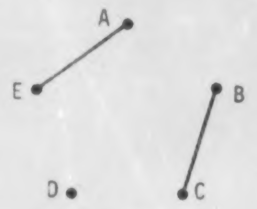
Case I: One connection. Using the definition of "different" introduced in the statement of the problem, we see that there is only one way in which a single connection can be made.



There is no figure having only one connection which is different from this one. That is, every other figure with a single connection can be obtained from this one by relabelling the dots.

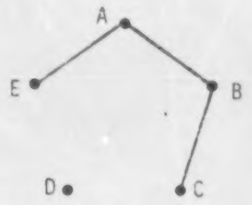
Case II: Two connections. There are two different ways in which two connections can be made.



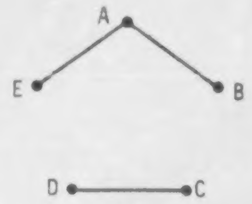


Every figure with two connections can be relabelled to have the same connections as exactly one of these two figures. The first of these figures cannot be relabelled to have the same connections as the second. These figures can be viewed as arising from the figure in Case I by adding a new connection in two distinct ways. What are these distinct ways?

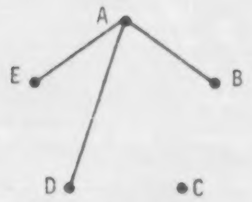
Case III: Three connections. There are four different possibilities in this case.



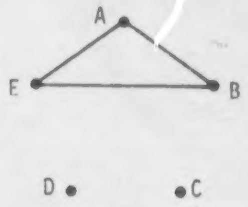
(a)



(b)



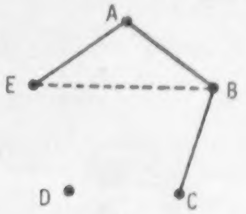
(c)



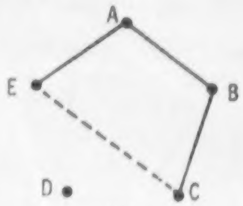
(d)

How can these four possibilities be identified? One method is to use the idea introduced at the close of the discussion of Case II. That is, consider each of the two different figures with two connections and ask "Where can a third connection be added?" Figure (a) can be obtained from either of the figures of Case II, as can figure (b). Figures (c) and (d), however, can be obtained only from the first figure of Case II. In each instance verify how the figure ((a), (b), (c), or (d)) can be obtained from one of the figures in Case II.

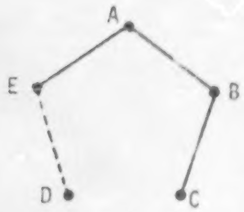
Case IV: Four connections. We continue to use the idea which proved effective in Case III. That is, we examine each of the figures in Case III and we ask where another connection can be made. To begin we consider figure (a) in Case III and we ask, "Where can a fourth connection be added?" There are the following possibilities: (The fourth connection is shown as a dashed line.)



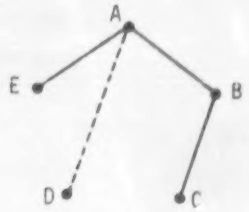
(e)



(f)



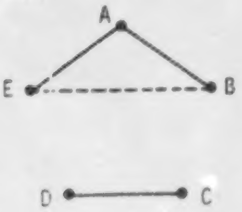
(g)



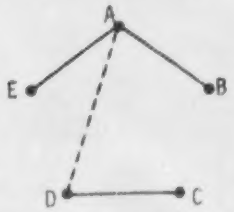
(h)

Each of these possibilities is different from the remaining three, and any other figure resulting from the addition of a fourth connection to figure (a) can be relabelled so as to be one of these.

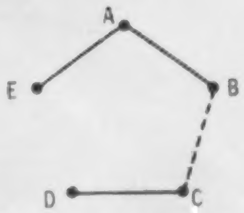
Continuing, we consider figure (b) of Case III. There are the following possibilities for a fourth connection:



(i)



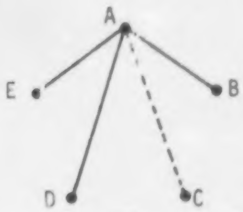
(can be relabelled as (h))



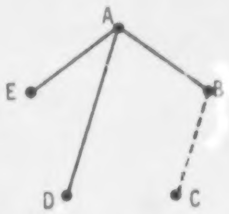
(can be relabelled as (g))

Of these three figures only the one labelled as (i) is new, that is, different from (e), (f), (g), and (h).

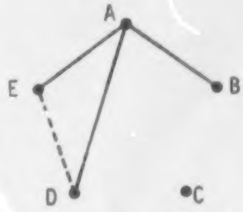
Next, if we begin with figure (c) of Case III, then there are the following possibilities.



(j)

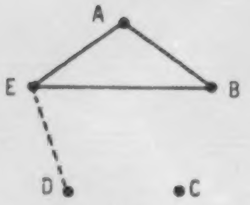


(can be relabelled as (h))

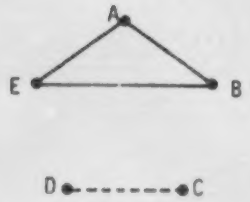


(can be relabelled as (e))

Of these three figures, only the one labelled as (j) is new. Finally, if we begin with figure (d) of Case III, then the resulting figures can be relabelled as (e) and (i). Indeed, they are:



(can be relabelled as (e))



(same as (i))

Throughout this discussion the connections drawn as dashed lines are to be considered the same for purposes of relabelling as those drawn as solid lines. The dashed lines were used only to distinguish the added connections at each step.

Summary

There is one way to make one connection.

There are two different ways to make two connections.

There are four different ways to make three connections.

There are six different ways to make four connections.

Therefore, there are 1 + 2 + 4 + 6 = 13 ways of making four or fewer connections.

The important characteristic of this strategy is the systematic reduction of the problem into subproblems or special cases. The solution of all the special cases provides the solution of the original problem. It may be that the method developed to handle one special case will also work for others, or it may be that several different methods are needed for different cases. In this example, we found the results of the analysis of one special case to be very helpful in analyzing the next case.

Understand
Plan
Carry out
Think back

When is the strategy helpful?

Again, there is no easy way to describe the problems for which this strategy is particularly useful. Some examples may be helpful.

1. In graphing problems it is sometimes helpful to distinguish the cases in which the variable is positive, negative, or zero.
2. In geometry problems one might want to consider separately cases in which a triangle is acute or obtuse.
3. In number theory problems one might consider separately the cases in which certain numbers were even or odd, or multiples of three, etc.

A word of caution

In using this strategy it is important that all of the relevant special cases are analyzed. If a problem is decomposed into a number of subproblems, it is necessary that the solution of the original problem be obtainable from the solutions of the subproblems. It is sometimes easy to overlook one or more special cases, in which event the original problem may not be completely solved.

MOD 218 Problem Solving II

This MOD provides further experiences in problem solving. PREREQUISITE: MOD 217

OBJECTIVES:

At the completion of this MOD, you will be able to:

1. Solve problems without previous knowledge of which strategy to use.
2. Demonstrate problem-solving skills.
3. Help children solve problems.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Problem Solving
2. Blocks in three colors, blocks for building a triangular pyramid, grid paper, play money

PROCEDURE:

1. In MMP, Problem Solving, do Activities 4, 5, and 6.
2. Find or create a puzzle that requires the use of a problem-solving strategy. Laminate it for your file.

FINAL ASSESSMENT:

1. Bring all work sheets and your puzzle to the evaluation.
2. Be able to answer all questions relative to the objectives.

MOD 219 **Weather and the Coriolis Effect**
Inferring, predicting

PREREQUISITE: Our Planet in Space by Navarra and Strahler, pp. 102, 235, and 236. Know the direction in which the earth rotates.

OBJECTIVES:

1. Given a rotating table and chalk, you will be able to demonstrate the Coriolis Effect on both a clockwise and counter-clockwise "spinning table."
2. You will be able to relate the motion of the spinning table to the rotating earth by demonstrating how the earth appears to be moving both clockwise and counter-clockwise as seen from (a) the north pole, and (b) the south pole.
3. After demonstrating the Coriolis Effect on a rotating table, you should be able to predict how
   a) a "south bound wind" is deflected in the northern hemisphere;
   b) a "north bound wind" is deflected in the northern hemisphere;
   c) a "south bound wind" is deflected in the southern hemisphere;
   d) a "north bound wind" is deflected in the southern hemisphere.
4. Given a weather map for a particular day, you will be able to predict the weather trend in your locality for the following two days, incorporating knowledge that pertains to prevailing winds, local wind shifts, temperature changes, and precipitation possibilities.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Our Planet in Space by Navarra and Strahler in Resource Center
2. Earth globe
3. ESS spinning table, chalk
4. Newspaper weather maps

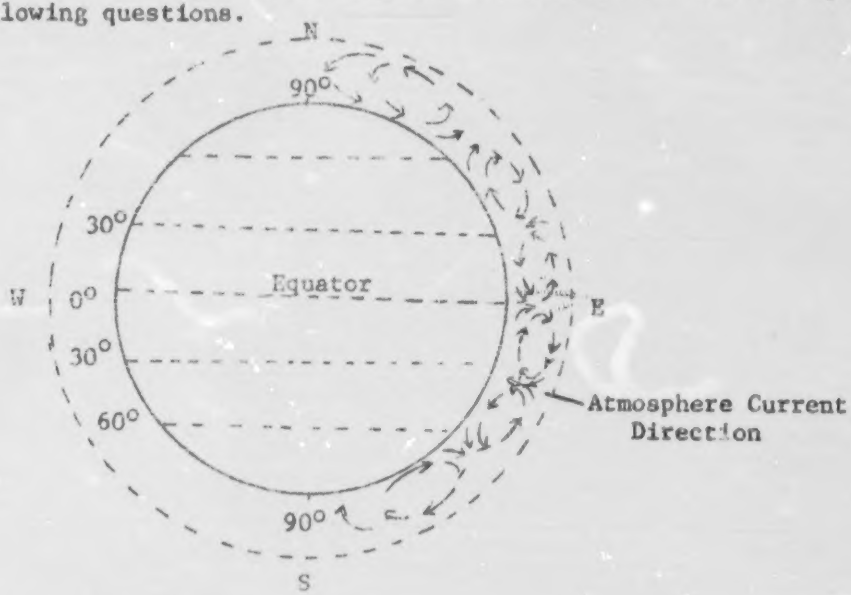
FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

If a child asks, "What causes the wind?," how would you answer as an elementary teacher? Sometimes the answer, "The wind blows because the air moves," is given. But a movement of air is the definition of wind and does not include the cause. Therefore, this response does not really answer the question. Air moves because of forces acting on it. These forces cause air to move vertically or horizontally across the earth, creating general wind patterns called the prevailing winds, for example, the trade winds. Keep these questions in mind as you do the activities in this MOD. What effect does air pressure have on wind direction? What effect does convection have upon wind direction?

Study the diagram below showing a cross-section of the earth and its atmosphere to answer the following questions.



1. Why does air rise above the equator?

2. What happens to the temperature of air as it rises?

3. How does this temperature change affect the density of rising air?

4. What causes the air to descend to the earth, for example, at latitudes 30°, 90°?

If the earth were not rotating, the prevailing winds would be north or south winds. However, the earth is rotating and this causes a deflection of the winds away from their original paths. This effect known as the Coriolis Effect is determined by the direction that the earth rotates and the original direction the wind moves. You will observe how this effect works in one of the following activities.

Answer these items.

1. Describe the direction of earth rotation.

2. Cite physical (natural) evidence for the direction of rotation.

Prevailing Winds of Western Kentucky

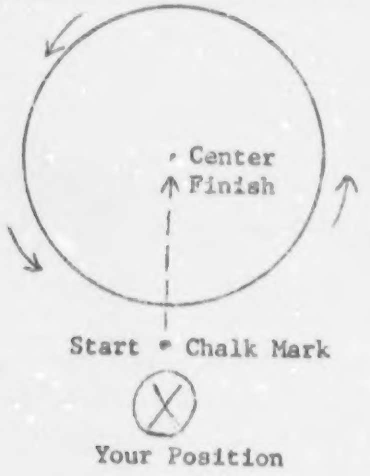
Examine a series of weather maps from any regional daily newspaper or the bulletin board. You will note that the high and low pressure cells approach Western Kentucky from a certain general direction. Also notice the directions of winds moving around high pressure and low pressure cells.

Coriolis Effect

The rotation of the earth has a direct influence on the prevailing winds. As was previously noted, the prevailing winds would be north or south if the earth were stationary. They are, however, deflected. It is hoped that this exercise will point out how this deflection occurs.

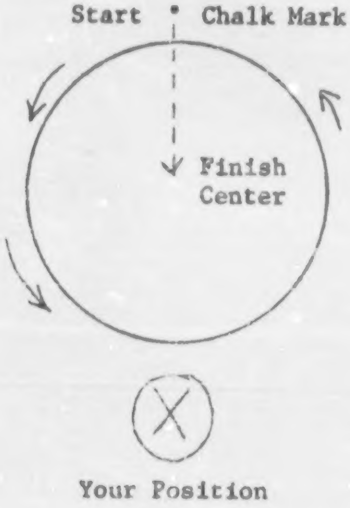
1. Use the ESS spinning table and chalk. Spin the table counter-clockwise. While the table is spinning, attempt to draw a straight line from the side of the table closest to you to the side farthest away. See diagram below. The line will be deflected; that is, it will not be straight. Has the line been deflected to the right or the left of its original path? __________.

Counterclockwise Spinning Table



Spin the table, again counter-clockwise, but this time attempt to draw the line from the far side of the table to the side nearest you. Which way has the line been deflected relative to its original path? __________. See diagram below.

Counterclockwise Spinning Table



Spin the table clockwise and repeat drawing the lines toward you and away from you. Which way has the line been deflected when drawing the line away from you? ____________ Toward you? ____________ Is the direction that you draw the line a factor in causing different directions of deflection? __________ Is the direction of rotation of the table a factor influencing the direction of deflection? ____________ How does speed of rotation influence the deflection?

2. Using an earth globe, imagine yourself out in space looking "down" at the north pole of the earth. Would the earth appear to be moving clockwise or counter-clockwise? Name its apparent direction. ______________

Now look at the south pole of the earth. From your vantage point in space, how would it seem to rotate? ______________ Use this information to summarize the exercise with the table and to point out the analogy between the spinning earth and the spinning table. Important points to include in your analogy are:

> The analogy of the direction of rotation and the hemisphere of earth.
> The analogy of the direction of chalk mark and the direction of wind.

You may use the reverse side of this paper to write your analogies.

3. Finally, erase all chalk marks on the table and draw a circle approximately one inch in diameter as near to the center as you can estimate. Print an "L" in the middle of this circle to indicate a low pressure area. Such an area on earth has less atmospheric pressure than the surrounding air. Because high pressure air moves into lower pressure regions, you will be drawing lines from the edge of the table to the circle in order to simulate the Coriolis Effect on a low pressure cell. Attach paper so that center of paper covers circle drawn on center of board.

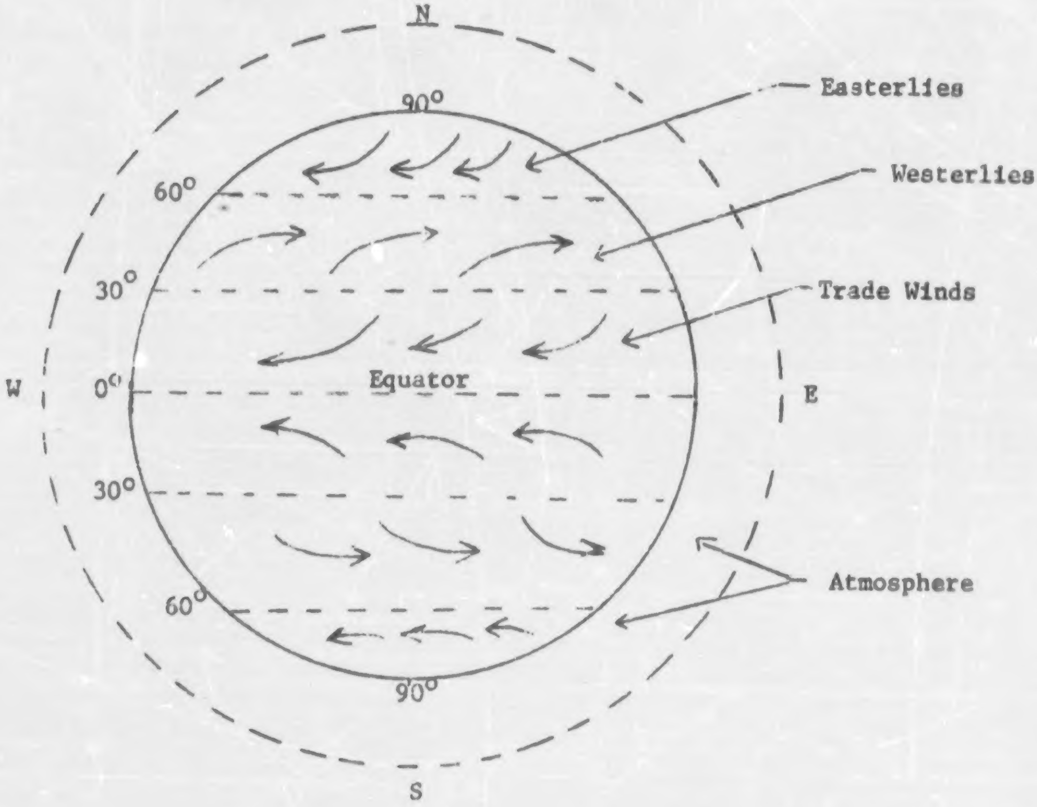
Spin the table (counterclockwise) with your paper attached to it. Keep it spinning with one hand and attempt to draw lines rapidly toward the center cirle. Do this until a pattern emerges. This pattern will represent a low pressure cell (cyclone). Compare this with the high altitude pictures in ESCP, Investigating the Earth, pp. 164-167. Do you notice any similarities? ________ Differences? ________ How would the "in rushing" wind affect the air in the center? ______________ ______________ Would it move the center air clockwise or counter-clockwise? ______________ In spinning the table counter-clockwise, you have simulated the Coriolis Effect for a particular hemisphere. Which hemisphere? __________

Repeat the same procedure, but spin the table clockwise. Your pattern should represent a low pressure cell in which hemisphere? ______________

4. In your immediate environment there is other evidence of the Coriolis Effect. For example, water goes down the drain a certain way in the northern hemisphere. Go to the nearest lab sink and observe this swirl pattern. Does the water swirl clockwise or counter-clockwise? ____________ Does this phenomenon correspond to a high pressure or low pressure cell? _________

In an appropriate place observe a cigarette smoke pattern in calm air. If possible try to observe this phenomenon from above and report the direction that the smoke seems to spiral. Is it clockwise or counter-clockwise? _________ Does the spiral of the smoke correspond to a high pressure or low pressure cell? _________ How do you think the spiral occurs in the southern hemisphere?

Review on the back of this page the analogy between the activity with the spinning table and the wind patterns of the earth as shown in the illustration below. Stress the reason for the deflection direction of each of the six zones in the illustration.


N
90°
60°
30°
W
0°
Equator
E
30°
60°
90°
S
Easterlies
Westerlies
Trade Winds
Atmosphere

MOD 220 Preparation for Video Lesson on Number Theory

This MOD is designed to plan a short lesson in some area of number theory. You should form groups of four to eight students for this MOD and also MOD 221.

OBJECTIVES:

At the completion of this MOD you should be able to:

1. Plan a lesson utilizing inquiry teaching, questioning, and "hands-on" materials.
2. Teach a small group with a degree of confidence.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Number Theory
2. 16 mm film projector and video tape player
3. References and materials in Resource Center
4. MMP, Math Tape #5 in Resource Center
5. Film, I Do and I Understand Resource Center

PROCEDURE:

1. Read Section B, "General Methodology Competencies for the Teacher of Elementary Mathematics," included in the MOD.
2. View the videotape, MMP Math Tape #5 and the film, I Do and I Understand.
3. With your group discuss the filmed classes using as guidelines the competencies mentioned in procedure #1.
4. Develop a lesson plan for 25-30 minutes to be used in MOD 221. Include in the plan: a) Title b) Description of the class with general ability and grade level c) Content and process objectives d) Materials needed e) Introductory activities f) Procedure and g) Evaluation plan.

FINAL ASSESSMENT:

After you have developed your plan discuss it with one of the ISMEP faculty members and have it approved before proceeding with MOD 221.

SECTION B

General Methodology Competencies for the Teacher of Elementary Mathematics

The elementary school mathematics teacher:

1. when given a list of alternatives for teaching mathematics to children, will be able to identify those alternatives that are more conducive to an inquiry style of teaching.

2. when in a mathematics teaching role in the actual classroom, will be able to create situations that incite enthusiasm by the children. The ability to "incite enthusiasm" will be evidenced by the following types of behavior:

   (a) children respond eagerly to the teacher's directives.
   (b) children ask, or by their behavior imply, curiosity type questions such as, "what if...?","can I do it?," "let's do this and see what happens," "don't show me, let me figure it out!"

3. when in a teaching role in the actual classroom, will employ divergent questions in initiating a student-centered, mathematics learning experience.

4. will invite children's participation in an activity through questioning rather than lecturing.

5. will be able to encourage exploration and systemization and discourage haphazard generalizations by children.

6. will be able to respect and acknowledge contrary opinions expressed by children when such opinions can be demonstrably based on a logical sequence of thinking.

7. will be able to withhold value judgements of children's answers when lack of expression of such value judgements leads to more discussion and/or exploration.

8. not only permits but encourages discussion among children when an activity is in progress.

9. will be adept at procuring and /or modifying materials and planning situations necessary for "hands-on" concrete learning of mathematics.

10. will show evidence of using materials and/or creating situations to help children become involved in concrete mathematical experiences.

11. will emphasize process development and assessment.

12. will recognize that understanding is more important than getting the answer right.

MOD 221 Videotaping and Reviewing Lesson

PREREQUISITE: MOD 220

This MOD is designed to provide an opportunity for you to conduct a mini-simulated teaching experience and to analyze it according to a set of general teaching competencies.

OBJECTIVES:

At the end of this MOD you will be able to:

1. Identify some competencies where you have greatest teaching strengths.
2. Identify competencies which need more practice.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Video-recorder
2. Materials in the Resource Center
3. Lesson plan from MOD 220
4. Resource books in Resource Center

PROCEDURE:

1. With your working team of four to eight peers identified in MOD 220, your plan developed in MOD 220, and equipment and supplies from the Resource Center, you will conduct a short activity-oriented lesson (approximately 30 minutes) while the lesson is videotaped.
2. After all members of the team have been taped, the team and at least one member of the ISMEP staff will view the tapes and discuss them in the context of the competencies listed in MOD 220. Your lesson will probably not involve all of the competencies.

FINAL ASSESSMENT:

The MOD will be completed upon review as outlined in "Procedure." On the competency sheet from MOD 220, indicate the competencies with greatest strength with a "+," those needing additional work with a "-," and those which do not apply in this activity with a "0."

MOD 222 Teaching Children: Science

PREREQUISITES: MOD 211

This MOD is designed to allow you and your partner to teach the two-period lesson planned in MOD 211.

OBJECTIVES:

Given a group of 8-10 elementary children of the grade for which you developed a plan in MOD 211, you and your ISMEP partner will teach the lessons you developed. Each partner should assume the major role on one of the days. At the conclusion of the lessons you should be able to identify areas of your teaching where you had greatest success and areas where improvement is needed. You will be able to suggest a plan of remediation for those areas needing improvement. Part or all of the lessons may be videotaped.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Plan developed in MOD 211
2. Materials identified in MOD 211
3. Video tape recorder if needed

FINAL ASSESSMENT:

Each team should sign up for a review session with the instructor as soon as possible following the teaching experience.

MOD 223 Probability in the Elementary School II

This MOD continues with the basic concepts of probability.

OBJECTIVES:

At the conclusion of this MOD, you will be able to:
1. Understand and determine a sample space.
2. Understand and use the term "event."
3. Utilize some counting techniques.
4. Compute probabilities.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Probability and Statistics
2. Enrichment Mathematics for the Grades, 27th Yearbook by NCTM

PROCEDURE:

1. In MMP, Probability and Statistics, do
   Activities 4: Parts 1, 2, 3, 4, 5, and 6
   5: Parts 1, 2, 3, 4, and 6
   6: Parts 1, 2, 3, 4, and 5
2. Plan a game or activity for determining probability as you learned in Activity 6 in the MMP book.

FINAL ASSESSMENT:

1. Bring all work sheets and the activity to the evaluation.
2. Be able to answer all questions relative to objectives.

MOD 224 Probability in the Elementary School III

This MOD deals with children handling the concept of probability.

OBJECTIVES:

At the completion of this MOD you will be able to:
1. Have insight into the child's view of probabilistic situations.
2. Introduce probability concepts to children by the use of games.
3. Use probability models to understand real-world situations.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Probability and Statistics
2. Enrichment Mathematics for the Grades, 27th Yearbook of NCTM
3. Spinner, paper, colored pencils (If not found in MOD tray, locate in Resource Center)

PROCEDURE:

In MMP, Probability and Statistics, do
Activities 7: Parts 1, 2, and 3
8: Parts 1a, b, and 2 (laminate game)
9: Problem A (1, 2, and 3), Problem B (1 and 2), General Questions (1)

FINAL ASSESSMENT:

Bring all work sheets and constructions to the evaluation.

MODULE 225 MISSING FROM DOCUMENT PRIOR TO ITS BEING
SHIPPED TO EDRS FOR FILMING.

BEST COPY AVAILABLE.

MOD 226 Building Teaching Games

This MOD will allow you to explore the games in the Resource Center and suggested games in reference materials there and permit you to copy or create similar games for a class room on the grade level in which you are interested.

OBJECTIVES:

Upon completing of this MOD you will:

1. Be familiar with games that are currently being used in many mathematical learning situations
2. Have a permanent nucleus of a collection of games for your elementary students
3. Have a new appreciation of the significance of teaching mathematics through the use of games.

INSTRUCTIONAL REFERENCES AND MATERIALS: (No MOD tray for this MOD, find all needed materials in Resource Center)

1. Brevard County Lamps
2. NCTM Games and Puzzles
3. Cratty: Active Learning: Games to Enhance Academic Abilities
4. Bitter, Mikesell, and Maurdeff: Games and Ideas
5. Kennedy and Michon: Games for Individualized Mathematics Learning
6. Let's Play Games
7. Make It and Take It Games
8. Ball and Coxeter: Mathematical Recreations and Essays
9. Games in ISMEP Resource Center
10. Construction paper
11. Felt tip pens
12. Poster paper
13. Ruler
14. Laminator
15. Copier

PROCEDURES:

1. (a) Review game activities in the Brevard County Lamp for the grade that you teach.
   (b) Review games in the Center.
   (c) Familiarize yourself with several of the reference books.
2. Select the mathematical topics for which you would like to have games to use.
3. Make at least five to six games for your permanent collection.
4. Make copies of instructions for at least ten other games that appeal to you.

FINAL ASSESSMENT:

Bring all games and materials to the evaluation session.

MOD 227 Teaching Children: Probability

PREREQUISITE: MODs 214, 223

OBJECTIVES:

1. Plan a lesson suitable for four to five fifth grade elementary students.
2. Teach the lesson to four or five students.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Indiana Model Teaching video program, "Introduction to Probability"
2. Elementary mathematics textbooks, found in Resource Center
3. SMP, Probability and Statistics
4. Video-tape recorder

PROCEDURE:

1. View the video-tape: "Introduction to Probability."
2. Plan your lesson for four to five fifth graders on some basic probability concepts.
3. Consult with the instructor(s) relative to your plan.
4. Teach your lesson at an announced time and place.

FINAL ASSESSMENT:

Your instructor will discuss and evaluate the teaching experience with you.

MOD 228 Using Manipulatives in Teaching Mathematics: Cuisenaire Rods
A Seminar

This MOD is designed to provide an opportunity to discover new applications for selected manipulatives, with emphasis on Cuisenaire rods, for teaching math concepts to children.

OBJECTIVES:

At the conclusion of the seminar each student should be able to identify concepts and explain and/or demonstrate the use of selected manipulatives for modeling the concepts that have been covered in the seminar.

INSTRUCTIONAL REFERENCES AND MATERIALS:

Handouts and working materials will be provided at the time of the seminar.

INSTRUCTIONS:

Sign up on the MOD shcedule sheet if you choose to complete this MOD; such a schedule sheet will be posted soon after the semester begins.

FINAL ASSESSMENT:

Completion of this MOD will be accomplished by attending the seminar and performing as outlined in the objectives.

MOD 229 Collecting and Classifying Insects
Classifying

OBJECTIVES:

Select either objective 1 or 2.

1. Given a collecting net and killing jar, you will collect, identify the order names, and properly mount for display enough insects to accumulate at least 40 points. Points accumulate as follows: 3 points for each different order represented; [illegible] points for each insect identified according to its family name (no common names).
2. Given a collecting net and killing jar, you will collect at least 20 different insects (not spiders) for which you either know or can easily find the common names. You will then create an identification key suitable for grades 3-6.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Insect net, killing jar, container for mounting insects, insect labels, insect pins, insect mounting boards
2. Jaques, How to Know the Insects
3. Jaques, How to Know the Beetles
4. Zim and Cottam, A Golden Nature Guide to American Insects

FINAL ASSESSMENT:

Bring to your instructor the mounted labeled collection. If you selected objective 1, you will demonstrate your proficiency at using an insect key by following the traits of an insect of your choice through the key. If you selected objective 2, the instructor will attempt to identify a random insect from your collection by using your key.

PROCEDURE:

To collect insects one must have a few basic pieces of equipment such as a collecting net and a killing jar. Some killing jars use a plaster of Paris base saturated with a poison. When an insect is caught in a net it is immediately transferred to the killing jar for a quick kill. The faster the kill is, the better will be the conditions of the specimen. Certain precautions must be observed when the poison is one like a compound of cyanide. This substance is a "fast killer" of insects and it is also a fast killer of humans if it is introduced into the blood stream. The main precaution that one must observe in using a cyanide killing jar is that, if the jar breaks - if it is dropped, for example, the person should use extreme care in cleaning up the broken glass. Do not touch such glass with your hand because you may get cut with a cyanide-coated fragment. Obviously this type of jar would not be suitable for elementary children, so in this MOD we will use a relatively safe type of jar containing ethyl acetate. This substance requires about the same precautions as rubbing alcohol, that is, it is flammable, it should not be taken internally and it should not be inhaled over a long period of time. Also, keep it out of the reach of small children.

To make a killing jar for small insects, for example, flies, bees, etc., fill the bottom of a baby food jar or similar jar with ½ in. to 1 in. of plaster of Paris and wait until it hardens. When it has set, dry it thoroughly in an oven or on top of a warm air vent. When the plaster is completely dry, saturate it with ethyl acetate and pour off the excess liquid. You must keep the jar tightly covered so that it will last as a killing device. The jar may later be "revived" by adding more ethyl acetate. Instead of a wide-mouthed baby food jar, a jar with a smaller neck that could be plugged with a cork would be even more suitable. In this MOD you will be supplied with the plaster, ethyl acetate and a jar. You will actually construct the killing jar for experience. Usually, ethyl acetate can be obtained at drug stores. Other substitutes are available, for example, carbon tetrachloride, benzene, or gasoline, but these items should also be used with caution.

Upon request, the instructor will sign out a collecting net to the student. Each student may collect and trade insects with other students in the class, but each student will present for inspection her completed collection. In this collection, each insect should be pinned and labeled according to directions presented in the book, How to Know the Insects, pp. 13-20.

Actually, the method of pinning and labeling insects is somewhat standardized for the purpose of easy identification and can be found in most books on the subject of insect collecting. Since your collection will not be of the professional type it is not necessary to adhere strictly to the directions. However, neatness and legibility should be of prime concern. Insect pins will be provided for you. The box in which you pin the creatures should have a lid, for example, a shoe box, an egg carton, a cigar box, etc. It should have some material on the bottom into which the pin can be stuck, for example, cardboard, styrofoam, cork strip, etc. Some insects are better preserved in small vials of alcohol. Such insects include aquatic species and caterpillars. We will provide small vials if they are needed.

Identification (relative to objective 1)

Read in one of the reference books the distinguishing characteristics of an insect. To some people an insect is "anything that crawls or flies like a bug." Needless to say, you will have an extremely difficult time using an insect identification key if you do not have an insect to begin with.

In MODs 104 and 106 you learned how to classify objects. The hierarchies you created in classifying these objects are similar to the biological hierarchy of taxonomy, that is, a classification scheme. The major categories of the biological hierarchy are presented below:

Phylum,
  Class,
    Order,
      Family,
        Genus,
          Species.

The insects form the class Insecta. This class, in turn, is a subgrouping of the phylum Arthropoda that inclues groups such as crawfish, lobsters, crabs, centipedes, millipedes, spiders, ticks, mites, and insects. From objective 1 and the hierarchy listed above, it is evident that the order of the insect has to be established before a key to family identification can be used. There are two procedures one might follow to identify the order and family of an insect. One method is based on the premise that you already know the common name of the insect. If this is the case, then it follows that a trivial amount of research will reveal the order and family name of this insect. Look, for example, in the index of a reference book. On the other hand, if the insect is totally strange to you, you will find the identification key helpful. However, some skill is necessary in using such a key. It takes keen powers of observation to read a description of an insect body part and to identify it, usually through a binocular microscope. It also takes perseverance and patience on your part - traits your instructors hope you will develop in this course. If you do not know the insect, find out the order of the insect by referring to the Key to the Orders of Adult Insects, starting on page 40 of the reference How to Know the Insects. Once you have identified the order of insects turn to the individual family key for that particular order and identify the specimen according to family (family names end in "ae").

Optional activity: Obtain an insect from your dorm, bed, dining room, etc., and after identifying it, check in the reference book cited above to find out whether the insect is a harmful or beneficial insect or just a pest.

Making a Key (relative to objective 2)

First collect 20 different insects and arrange them in a hierarchy similar to those you formulated in MODs 104 and 106. The terminology should be at the average level of a fourth grader. If you use a word that might not be understood, such as "antennae," explain it in a separate section. Try to be original in your terminology yet specific enough to avoid confusion. When your key is finished, try it out on a friend. Assume that if this friend cannot follow your key then it is quite probable that a fourth grader cannot follow it either.

MOD 230 Photography I
Controlling variables

PREREQUISITE: The instructor will hold a group session for those students interested in photography MODs 230 and 231.

OBJECTIVES:

1. Given a piece of exposed film, you will be able to describe its material components and the manner in which it is affected by light.
2. Given an adjustable camera and film, you will be able to demonstrate good technique in taking a picture of some object in the classroom.
3. Given a piece of film and necessary equipment, you will describe and/or demonstrate proper techniques you would use in developing the film. See the instructor for help.
4. You will be able to describe the processes involved in developing a film.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. A Pentax camera and Kodak Plus-X Pan 35 mm. film, ASA 125
2. Instruction manual for the Pentax camera
3. This MOD, pp. 2-5

FINAL ASSESSMENT:

Be prepared:
1. to load the film in the camera;
2. to set the ASA reading to the value given by the instructor;
3. to adjust the camera for taking a picture by first setting the shutter speed and then determining the aperture setting;
4. to adjust the camera for taking a picture by first setting the aperture and then determining the shutter speed;
5. to adjust to the proper range setting by focusing on an object in the room;
6. to demonstrate to the instructor your ability to load the film in the developing tank;
7. to describe to the instructor the technique you would use in developing the film;
8. to demonstrate to the instructor that you know the relationship that exists between the aperture setting and the shutter speed control.

PROCEDURE:

Some precautions to be observed when working with a camera:

1. The camera costs $100.00 plus; therefore, do not drop it or handle it in a rough way.
2. Never remove any camera parts.
3. Never force any of the camera working parts.
4. Do not turn the shutter speed control past the 500 mark when turning the knob in a clockwise direction.
5. Do not turn the shutter speed control past the [illegible] mark when turning the knob in a counter-clockwise direction.
6. Seek help from an instructor if you do not understand the camera instructions
7. Do not work with a camera until you have read the accompanying instructional material.
8. Check out a camera from an instructor and return the camera to an instructor when it is not in actual use for study. Cameras may not be signed out for more than 24 hours at a time.

General Information

Photographic Film and Light:
Photographic film can accumulate light. What does this mean? We might compare this statement with the relationship that exists between light and the eyes. We know that the eyes are sensitive to a particular area of the electromagnetic spectrum, namely the visible spectrum which ranges from violet (shorter wave lengths) to red (longer wave lengths). The eyes are sensitive to the intensity of only the visible spectrum and will send messages to the brain which will register the intensity or brightness of light. We see objects that reflect light from the source to the eye. An object does not become brighter as we keep looking at it even though light keeps coming from the object to the eye. This is the same as saying that the eye does not accumulate the light as it keeps coming to the eye from the object. If it did, the object would become brighter and brighter with time. The explanation for this is that, as light reacts with the eye, the eye can only send nerve messages to the brain and not the actual chemical change that takes place in the interaction between the light and the eye cells. In film the light affects the materials of the film, and the reaction products accumulate with time. The longer light shines on a piece of film, the greater will be the accumulation of the reaction products. A good example which demonstrates this principle is the following. Suppose you look at the sky at night and you can see 2500 stars. No matter how long you look at the same star area, you will not be able to see more than 2500 stars. If you set a camera and expose the film for ½ second you might also see 2500 stars on the picture. However, if you expose that same film for 3 minutes, you might get many more stars on the picture. In a short exposure of the film, light coming from some stars is so weak that it causes only a minor reaction on the film which does not show up on the picture. With a longer exposure, the reaction products accumulate to the degree that stars not visible to the naked-eye show up on the picture.

What is Film?
Photographic film which we use in most cameras and from which negatives are made is composed of three materials. First it consists of a transparent sheet of clear plastic. This serves as a backing or supporting material for the other two materials. Second, on this backing is placed a fine, thin layer of gelatin in which is embedded the third substance consisting of several chemicals. These chemicals include silver bromide and silver chloride (silver halides) which are the substances that react with the light. These substances become light sensitive as soon as they are mixed with the gelatin and must be kept in darkness. It is only when the film is placed in a camera that it should be exposed to light. This is done by opening a shutter which allows light to enter the lens and reach the film. From what has been said above it should be apparent that light that reaches the film will react with the silver bromide and silver chloride on the film and produce reaction products. In reaction products the silver bromide and silver chloride molecules are slightly changed. The exact nature of the change is not known. It should also be apparent that the longer the camera shutter is open, the greater will be the accumulation of the reaction products.

The Paper:
Photographic paper is in many ways similar to photographic film. The main difference is that the paper does not have a transparent base like film has. Instead, photographic paper is a fine white paper with a protective coating covered by a light-sensitive emulsion similar to that on film. Unlike the film emulsion, however, the paper emulsion usually is not pan-chromatic and does not react to all visible light. Because it is most sensitive to blue-greens, it is possible to open most photographic papers under a dim yellow or red light without causing a chemical change in the emulsion. If these papers are exposed to the light of an incandescent bulb or to sunlight, however, there will be a chemical change in the emulsion just as these is in film.

The Negative:
Suppose that a camera is loaded with panchromatic film and that you are ready to take a picture. You press a button, and there is a click indicating that (a) light has entered the camera through an opening in the front, (b) light has struck the film, and (c) the opening has closed again. The silver halide particles in the emulsion of the film have trapped the light that has struck them. If you could examine the film at this point you would see no difference from unexposed film. However the light-sensitive silver halide particles have changed in some manner not completely understood by scientists.

When this exposed negative is placed in a solution called a developer, microscopic particles of silver form wherever light has struck the emulsion. The more light the film receives, the more silver is formed; where no light has struck, no silver particles form. These particles of silver are so tiny that they look black instead of bright and shiny.

After the developing solution has changed the light-struck silver halides into silver, there are still parts of the emulsion where light did not strike that contain light-sensitive silver halides. If you were to let light fall on the film these parts also would darken with the chemicals in the developer.

To keep the unexposed portions of the film from darkening after the developer has finished its work, the film is rinsed in water and then it is placed in a fixing bath or fixer. This fixer, sometimes called hypo by photographers, does several things. It stops the action of any developer that might still be on the film; it dissolves from the emulsion any silver halides that were not affected by light; and it hardens the emulsion to help protect it against scratches. All that is left in the emulsion are the microscopic particles of silver where light struck the emulsion when the camera shutter clicked open and shut. Because the film looks dark where there was light and transparent or light-colored where there was darkness, it is called a negative. The negative, therefore, shows where light struck the emulsion, and where it did not.

The Positive or Print:
Once a negative has been developed and fixed, it is washed in water and dried. To make a picture or print from it, light is allowed to pass through the negative onto a piece of photographic paper. Where the negative is darkest, little or no light gets through to the paper, and where the negative is light-colored or transparent, much light gets through to the photographic paper. In the emulsion of the paper, light is trapped in much the same way as it was trapped in the film at the time the picture was taken.

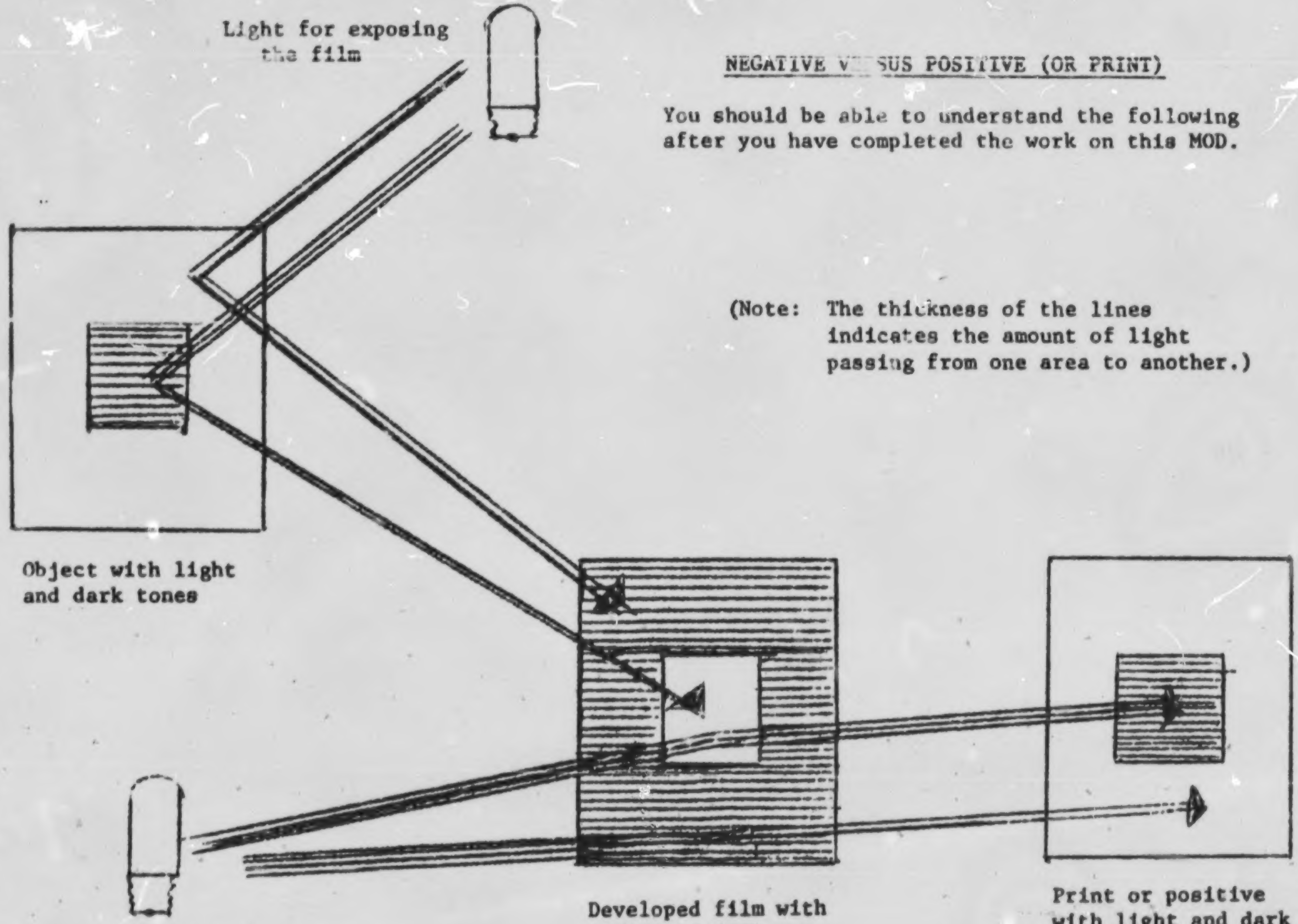
To complete the picture, the exposed paper is put into a developer similar to the one used for the negative. In the developer the silver halides that were exposed to light release their silver and it shows up as black or dark grey particles. If more light strikes the paper, more metallic silver is deposited in the emulsion. Where no light strikes the emulsion, there is no silver deposited and the paper still looks white.

When the developer has finished working on the light-struck silver halides, there may still be unaffected silver salts on the paper where light did not strike. These must be removed by bathing the paper in a fixer, just as the film was bathed in a fixer. When all the unaffected silver halides have been removed, the paper is washed in water and dried. It is now a finished photographic print. The areas that were dark in the negative have now been restored to white in the print, and the transparent areas of the negative have become black in the print. The finished photographic print is a positive or the opposite of a negative.

NEGATIVE VERSUS POSITIVE (OR PRINT)

You should be able to understand the following after you have completed the work on this MOD.

(Note: The thickness of the lines indicates the amount of light passing from one area to another.)


Light for exposing the film
Object with light and dark tones
Developed film with light and dark areas
Print or positive with light and dark areas
Light for exposing the print

MOD 231 Photography II
Controlling variables, interpreting data

PREREQUISITE: MOD 230, "Photography I"

OBJECTIVES:

1. You will be able to demonstrate your proficiency at manipulation of the shutter speed control and aperture of the camera by presenting your picture of a friend taken in a lab using available light, that is, with no flash bulb or special lights. The minimal acceptable quality will be such that the picture has enough contrast to show facial features.
2. You will be able to demonstrate your proficiency at manipulation of the variables of the camera by presenting a picture which shows an illusion of motion in which the subject which is actually moving appears stationary (in focus) while the stationary background appears in motion (blurred).
3. After receiving instructions, you will demonstrate your proficiency in developing film and prints by presenting the developed negatives and some developed prints. Although the quality of the film and prints may possibly be poor, you should be able to interpret the data and state reasons for such quality.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. This MOD, pp. 2-3
2. Instructors and students who have completed this MOD
3. A Pentax camera. Kodak Plus-X Pan film, necessary darkroom materials
4. Instruction manual for the Pentax camera

FINAL ASSESSMENT:

Present to the instructor the pictures that you have developed. Be prepared to give reasons for the quality and discuss the results of your photographic work.

PROCEDURE:

You will be given a film cartridge containing enough film to take 10 pictures. The film in the cartridge is Kodak Plus-X Pan and has an ASA speed of 125. With this film take 10 pictures that will satisfy the requirements listed in the objectives of this MOD. Then use the following procedure for processing the film, and plan to show the finished products to an instructor for evaluation of your results.

Preparation of a negative film to be used in making prints and the making of prints from the negative:

1. Rewind the film back into the film cartridge according to the instructions attached to the camera.
2. Remove the cartridge from the camera and, in the dark, open the film cartridge and remove the film.
3. Place the film on the developing tank reel. Then place the entire system in the developing tank and apply the tank cover. All of this must be done in the dark.
4. Turn on the lights and proceed to develop the film as follows:
   - A. Prolonged contact with the developing solutions may cause skin irritations; therefore, wash your hands frequently.
   - B. Developing the film: Measure out 350 ml. of D-76 Kodak developer and pour it into the developing tank. Develop for 8 minutes. Every 30 sec. or so pick up the tank and gently "slosh" the fluid around. This insures that the chemical is touching all parts of the film.
   - C. Pour out the developer into a bottle marked "used developer."
   - D. Without removing the lid, run water through the hole in the lid for 1 min. This will rinse the remaining developer off the film.
   - E. Measure out 350 ml. of fixer for film and pour it into the developing tank. Fix for 4 min.
   - F. Pour the fixer into a bottle marked "used fixer for film."
   - G. Remove the cover from the developing tank and rinse the film by running room temperature water into the tank for 10 min.
   - H. Fill a 1000 ml. beaker with tap water and add 1 cap-full of photo-flo solution. Mix the solution. Take the reel with the film out of the developing tank and dip it into the photo-flo solution several times.
   - I. Hang up the film by attaching a clamp to one end. Allow it to dry for 1 hr. This completes the development of the negative film.

5. In order to make prints from the negative you will need the enlarger. Make an appointment with an instructor who will explain how you should use the enlarger.

6. After the print paper has been exposed with the enlarger, develop the print as follows:
   - A. Note: You may have the dark room safety light on at all times when you are making prints. It is the amber-colored light.
   - B. Set up 3 developing pans next to the sink in the dark room. From left to right place the following solutions into the trays to a depth of ¼ inch: Kodak Dektol developer, stopbath for prints, fixer for prints.

C. Place a tray into the sink and run room temperature water in it. This is done by regulating both hot and cold faucets.

D. After the print has been exposed with the enlarger, place the print in the left-hand tray (developer) for 1 to 2 min. The correct time for developing is determined by looking at the film and watching the picture appear. When you feel that the picture shows good detail, it has been adequately developed.

E. When you feel that the print has been adequately developed, remove it from the developing tray and place it in the middle tray (stopbath). Leave it in the stopbath for about 1 min.

F. Remove the print from the stopbath, place it in the right-hand tray (fixer) and fix for about 4 min.

G. Remove the print from the fixer and place it in the tray with the running water. Wash it for 5 min.

H. Remove the print from the wash and place it on the dryer for 5-10 min. or until it is dry.

I. The picture is ready to be presented for evaluation.

J. When you finish developing the prints, wash and dry all glassware, countertop and trays. Replace all bottles to their original places, and, in general, be very thorough in leaving the darkroom clean and dry. Do not forget to turn off the dryer.

MOD 232 Isopods
Experimenting, formulating hypotheses, interpreting data

OBJECTIVES:

1. Observe isopods and by experimentation you will be able to find their preference for different amounts of moisture, temperature, food, and a diversity of materials.
2. From your observations and data about isopods, you will be able to infer what materials make up the environment of an isopod.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SCIS, Environments, Teacher's Guide
2. Aluminum foil, tape, light source, scissors, ice cubes, heat source, isopods, materials of your choice

FINAL ASSESSMENT:

1. Be prepared to present the instructor with a brief description of the experimental procedure which you followed:
    - a. the problem you tried to solve;
    - b. the variables involved and how they were manipulated and/or controlled;
    - c. your procedure including the equipment involved and how it was used;
    - d. your hypothesis;
    - e. your conclusions about the experiment.
2. Be prepared to discuss critically the results of the experiments with your instructor.

PROCEDURE:

After reading and studying SCIS, Environments, Teacher's Guide, pages 40-65, set up an experiment which will determine the preference of the isopod for different amounts of moisture, temperature, food, and a diversity of materials. Be sure to record the experimental procedure you used, the data you collected, the graphs you made, and the conclusions you drew based on your experimentation.

Before you proceed with your experiment, please have your experimental procedure approved by the instructor. You should use at least five isopods for each experimental design. Even though specific instructions are given in SCIS, Environments it is worthwhile for you to make up your own experimental design.

MOD 233 **Sound** and Wave Motion
Observing, inferring

OBJECTIVES:

1. Given (a) spoon and string and (b) yardstick and watch, you will demonstrate that sound travels better in solids than it does through air, and you will infer an explanation for what you observe.
2. Given (a) readings, (b) filmloops, and (c) a phonograph record on sound, you will be ready to discuss with the instructor any one of the following phenomena as it occurs in sound waves: reflection, refraction, interference, and Doppler effect.
3. Given rulers, rubber bands, strings, and pop bottles, you will be able to demonstrate any one of the following:
   a. emission of and variation of the pitch of a sound produced by a fixed ruler when it is struck;
   b. emission of and variation of the pitch of a sound produced by a rubber band when it is stretched and plucked;
   c. emission of and variation of the pitch of a sound produced by the air in a partially filled pop bottle when you blow over its top.
4. You will demonstrate with a system of real materials at least one sound phenomenon which might serve as an activity useful in teaching children.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Sections of physical science texts on waves and on sound*
2. Bell Telephone tape Science of Sound
3. Modern Learning Aids, Reflection of Straight Waves from Straight Barriers
4. Modern Learning Aids, Refraction of Waves
5. Ealing Corporation, Interference of Waves
6. Houghton-Mifflin's Doppler Effect in Light and Sound
7. 8 mm. filmloop projector
8. Tape player
9. Spoon, string, yardstick, watch, two identical tuning forks, rulers, rubber bands, pop bottles

FINAL ASSESSMENT:

See objectives above.

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* Dull, Metcalfe, and Williams, Modern Physics, Chapter 12
The reading pages of this MOD
Van Bergeijk, Pierce, and David, Waves and the Ear, pp. 25-28 and pp. 34-48

On Wave Motion

The fundamental common characteristic of all the waves to be described and studied is that they provide a mechanism for transferring energy from one point to another without physical transfer of material between the points. We might first consider the shock wave from an explosion. A sudden creation of heat raises a mass of gas in the near vicinity to a very high pressure. This pressure is then exerted on the air farther out. A pressure wave travels outward with a speed of 1100 feet per second, containing the energy required to compress the air.

A sound wave transmits energy in the form of a much milder disturbance of air. An example is that between a vibrating source and a receiver such as the ear and a microphone. Sound can also be transmitted as motions of the particles of a liquid or a solid. So sound is an example of a mechanical wave motion. Water waves constitute another type of mechanical wave motion; they can transmit energy capable of setting a ship into oscillation. Waves on a string or compressive waves in a spring are other examples of mechanical wave motion. Radio and light transmission involve electromagnetic waves. Here the disturbance is electric and magnetic in nature, as opposed to being mechanical. Sound waves, water waves, those in a string, or electromagnetic waves are only a few examples of two general types of waves. These are the transverse waves, in which the displacements of the particles of the medium are perpendicular to the direction of propagation of the wave, and the longitudinal wave, in which the displacements of the particles of the medium are parallel to the direction of propagation of the wave.

PROCEDURE:

1. Transmission of sound by solids:

a. Attach a metal spoon to the middle of a 4-ft. long string and let the spoon hit an object, for example, a wooden panel in the desk or table. Listen carefully to the sound produced as you hear it come through the air. Then hold each end of the string to your ears and let the spoon strike again. Note the difference in sound. Give a possible explanation for the difference.

b. Separate yourself from one of your fellow students by the length of a yardstick. Listen to her wrist watch at that distance and see whether you can hear anything. Then, have her put the back of her watch against one end of the stick while you place the other end of the stick at your ear. Do you hear anything? Give a possible explanation.

2. a. Read in a physical science book the sections on reflection, refraction, interference, and Doppler effect as related to sound waves.

b. Watch carefully the filmloops on reflection, refraction, interference, and Doppler effect. These filmloops depict water wave phenomena but they can be applied to sound waves as well.

c. Listen to the bands of the sound record on echoes, beats, and Doppler effect (bands 9, 16, 19 of the Bell Telephone tape.

d. The two identical tuning forks have the same frequency. A piece of wax added to one fork gives it a slightly lower frequency. If the forks are struck one right after another, the sound will seem to undulate in volume. This is an example of interference in sound called "beats." Associate this experience with what you hear from the Bell Telephone band on beats.

e. Be ready to discuss and demonstrate any one of the following as it applies in sound: reflection, refraction, interference, and the Doppler effect.

3. a. Place a ruler at the edge of a table so that about one-fourth of its length reaches out over the edge of the table. With one hand, press down hard on the ruler so that it is held close to the surface of the table near the table's edge. With a finger of the other hand pull down on the free end of the ruler, release it, and listen to the sound produced. Experiment by changing the length of the vibrating segment and relate this length to the pitch of the sound produced.

b. Stretch and pluck a string or rubber band and study the emission of its sound. How can you vary the frequency or pitch emitted by a system like this one?

c. Fill pop bottles with various amounts of water and observe what kind of sound is emitted when you blow across the top of each bottle. What arrangement results in a high pitch? What results in a low pitch? Can you arrange a musical scale and play a tune on your "pop bottle organ?"

d. What could you teach children about the instruments of an orchestra by demonstrating any of the three phenomena above?

4. Demonstrate for the instructor with a system of real materials at least one sound phenomenon which might serve as an activity useful in teaching children.

MOD 234 Metric Measurement Revisited

This MOD is planned to provide you with understanding and drill to strengthen your metric measruement knowledge and personal confidence and commitment in using metric measurement.

OBJECTIVES:

At the conclusion of this MOD you will:

1. Be able to handle the prefixes with confidence
2. Be able to think metric
3. Be able to compute in metrics
4. Describe some major advantages of the metric system for making measurement and calculations.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Measurement
2. Meter sticks and rulers
3. Balance scales
4. Liter containers
5. Metric scales
6. Work sheets attached to MOD

PROCEDURES:

1. View slide-tapes History of Metric Measurement and Advantages of Going Metric.
2. In MMP book, Measurement, do Activity 3, Sections 1, 2, 3, 4a, 5, and 6.
3. Plan an outdoor metric measurement activity for children of the grade level that you teach. Then do this activity.
4. Complete work sheets alone in so far as possible. Consult with partner and reference materials as needed.

FINAL ASSESSMENT:

1. Bring the completed activities and work sheets to the evaluation.
2. Take a 10-item paper-and-pencil quiz individually without reference.

A. Write five metric units of measurement by combining deci, centi, or milli with meter, gram, or liter. Give the meaning for each one. One is done for you.

1. Milliliter (0.001 liter)______
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

B. Use your knowledge of the three prefixes to complete the following statements.

1. The decimal system contains_______________digits.

2. How many years are in a century?_________________

3. 1000 millimeters is a meter. Thus, _____________years is a millennium.

C. Indicate if the following statements are true or false.

1._____1000 milliliters = 1 liter
2._____10 decigrams = 1 gram
3._____100 centimeters = 1 meter
4._____100 meters = 1 centimeter
5._____1,000,000 milligrams = 1 gram
6._____1 centimeter = 10 decimeters
7._____1 liter = 100 centiliters
8._____1 millimeter = 0.1 centimeter

D. Fill in the blanks below.

1. 2 grams = _____ centigrams
2. 5 liters = _____deciliters
3. 0.5 meters = _____ decimeters
4. 6 meters = _____ millimeters

E. Use a dictionary or other reference book to find the symbols for the following.

1. deciliter________
2. centimeter________
3. centigram _______
4. millimeter______
5. milligram ________
6. milliliter________

F. Write five metric units of measurement by combining deka, hecto, or kilo with meter, gram or liter. Give the meaning of each one. One is done for you.

1. kiloliter (1000 liters)________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

G. Use your knowledge of the three prefixes to complete the following statements.

1. A decade lasts for a period of _____ years.

2. A decagon has _____sides.

3. A kilowatt is electrical power of _____ watts.

H. Indicate if the following statements are true of false.

1. _____ One dekameter equals 10 meters.
2. _____ A hectoliter is larger than a kiloliter.
3. _____ 1000 kilograms = 1 gram.
4. _____ A dekaliter equals 100 liters.
5. _____ One meter is 10 dekameters.
6. _____ A kilogram is 10 times bigger than a hectogram.
7. _____ A kilometer equals 1000 meters.
8. _____ 100 grams equals a kilogram.

I. Fill in the blanks below.

1. 3000 grams = ________ kilograms
2. 40 liters = ________ dekaliters
3. 200 meters = ________ hectometers
4. 2000 grams = ________ kilograms

J. Use a dictionary or other reference book to find the symbols for the following.

1. meter _____
2. gram _____
3. liter _____
4. dekameter _____
5. hectoliter _____
6. kilogram _____
7. kilometer _____
8. dekagram _____

K. Fill in the blanks below with the best metric unit to use when measuring the following.

1. distance between cities ____________________
2. weight of a little bag of candy ____________________
3. fuel for an automobile ____________________
4. camera film size ____________________
5. length of a hot dog ____________________
6. weight of an airplane ____________________
7. weight of ground beef in a meat department ____________________
8. height of a person ____________________
9. weight of a person ____________________
10. distance swam in a pool ____________________
11. contents of bottle of eardrops ____________________
12. carbohydrate content of cereal ____________________
13. diameter of a large pizza ____________________
14. distance per hour an automobile travels ____________________
15. height of a mountain ____________________

L. Name 8 of the most commonly used units of measurement. ________

________ ________ ________ ________

________ ________ ________ ________

M. In the 1972 Winter Olympics an ice skater completed the 5000-meter speed-skating event in 8 minutes. What was his rate of speed in meters per minute? ________ In meters per second? ________

N. Estimate in metric units the measurement of each item below.

1. capacity of a bottle of milk ________
2. length of this paper ________
3. weight of your math book ________
4. height of a door ________
5. weight of a quarter ________
6. volume of a cup ________
7. length of a shoestring ________
8. capacity of a glass ________

CAN YOU FILL IN THE BLANK?

Problem: Find the equivalent metric measure for each problem.

Directions: Fill in the missing blanks.

1. 120 mm = ________ cm
2. 280 cm = ________ m
3. 2 km = ________ m
4. 3 L = ________ ml
5. 2.4 L = ________ ml
6. 5 kg = ________ g
7. 5000 mg = ________ kg
8. 6 g = ________ mg
9. 500 ml = ________ L
10. 6.82 t = ________ kg
11. 500 g = ________ kg
12. 150 m = ________ km
13. 0.5 kg = ________ g
14. 0.5 m = ________ km
15. 0.5 m = ________ cm
16. 5200 mg = ________ g
17. 2 m^2 = ________ cm^2
18. 7 cm^2 = ________ mm^2
19. 10.2 ha = ________ m^2
20. 22,000 cm^2 = ________ m^2

A METRIC MASTERY TEST

1. The ________ is the basic unit for measuring length in the metric system.

2. The ________ is the basic unit for measuring mass in the metric system.

3. The ________ is the unit for measuring capacity in the metric system.

4. The ______________ is used to measure temperature in the metric system.

5. To measure volume the answer would be expressed in ________meters, ________ centimeters, etc.

6. To measure area the answer would be expressed in ________ meters, ________ centimeters, etc.

7. In the metric system each unit of length is ________ times the next smaller unit.

8. Write the symbol for:

   a. meter ________

   b. kilometer ________

   c. centimeter ________

   d. millimeter ________

   e. liter ________

   f. gram ________

   g. Celsius ________

   h. cubic centimeter ________

9. What does the symbol m^2 stand for ? ________________________

10. Five cm^3 is the same as __________mm^3.

11. Write in the unit you would use to measure the following.

    a. container of milk ________

    b. a beef roast ________

    c. a length of rope ________

    d. a truckload of sugar beets ________

    e. a zipper ________

    f. a lawn ___________

    g. a room temperature _________

    h. electricity used ________

12. Match the approximate mass with the object.

________	a. 50 ml of water	1. 2 kg
________	b. a nickel	2. 80 kg
________	c. a grown man	3. 50 g
________	d. a small bag of sugar	4. 5 g
________	e. a large car	5. 2 t

13. Match the event with the most appropriate temperature.

________a. water freezes 1. 100° C

________b. a comfortable room 2. 37° C

________c. water boils 3. 0° C

________d. a cake bakes 4. 21° C

________e. normal body temperature 5. 160° C

14. Complete the following:

a. 1.6 m = ________ km = ________ cm

b. 0.4 cm = ________ m + ________ mm

c. 5 cm^2 = ________ mm^2 = ________ m^2

d. 260 g = ________ kg

e. 22.4 L = ________ ml

f. 1 m^3 = ________ cm^3 = ________ mm^3

g. 2.2 kg = ________ g = ________ mg

15. List an approximate customary system relationship for each of the following.

a. A meter is ________________________

b. A kilogram is ____________________

c. A liter is ________________________

d. A centimeter is __________________

16. Five g of water is about ________ ml = ________ cm^3 .

17. Simplify the following expressions:

a. $10^3 \times 10^4$ = ________

b. $10^5 \times 10^{-2}$ = ________

c. $10^5 \div 10^3$ = ________

d. $\frac{10^6}{10^{-4}}$ = ________

e. 0.0001 = $10^?$ ________

f. 10,000,000 = $10^?$ ________

18. Express in scientific notation.

a. 30,000,000 = ________________

b. 0.0000045 = ________________

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MOD 236 Shadow Sticks
Inferring, predicting, interpreting data

OBJECTIVES:

1. Given a clear plastic hemisphere and a black wax marker, you will trace out on the hemisphere the path of the sun throughout one day.
2. Given a shadow stick and a large piece of paper, you will record shadows and their times at least 7 times throughout a day during the second or third week of the term and throughout a day during the eighth or ninth week of the term.
3. Given the shadow data in 2 above, you will compare the two records and interpret the data obtained on the two days.
4. Given the shadow data in 2 above, you will find true north, and, consequently, all of the other directions.
5. Using the paper and shadow records in 2 as a clock, you will predict positions and lengths of shadows to occur one hour hence or two hours hence, and you will check your prediction when the shadows actually occur.
6. Given an earth globe, a tiny shadow stick, and paper, you will make shadow clocks for Murray and for locations
   a. having different longitude but the same latitude as Murray
   b. having different latitude but the same longitude as Murray
   c. having latitude and longitude different from Murray
7. Given the same materials as in 6, you will find where on the earth
   a. the sun is directly overhead;
   b. the sun is to the observer's north;
   c. the sun is coming up;
   d. the sun is setting;
   e. the sun is not visible at all today;
   f. the sun is visible all day today.

INSTRUCTIONAL REFERENCES & MATERIALS:

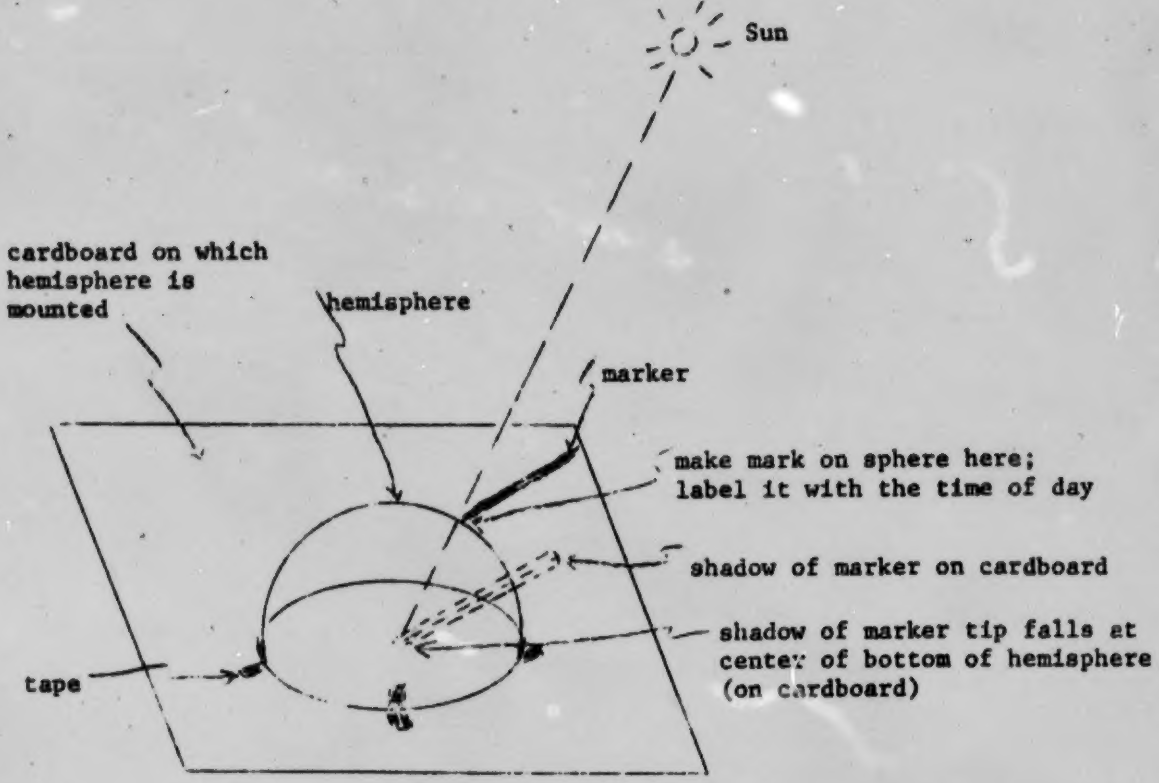
1. ESS, Daytime Astronomy, Teacher's Guide
2. Plastic hemisphere, black wax markers, paper, shadow sticks, earth globes, toothpicks, Plastick or clay

FINAL ASSESSMENT:

Be prepared to discuss with the instructor your records resulting from activities designated in objectives 1-7 above.

PROCEDURE:

1. Method for recording sun's path as designated in objective 1


Sun
cardboard on which hemisphere is mounted
hemisphere
marker
make mark on sphere here; label it with the time of day
shadow of marker on cardboard
shadow of marker tip falls at center of bottom of hemisphere (on cardboard)
tape

IMPORTANT: The hemisphere must be oriented in exactly the same way throughout the time observations are made.

At the end of the day, connect by a smooth path the 6 or 7 marks made throughout the day. Using the plastic curved rulers in the MOD tray, determine true south and true north from inspection of the path drawn. Using these same rulers, determine also the sun's maximum altitude and the azimuth of its rising and setting positions.

2. Regarding objectives 2 through 5
Use the shadow sticks and paper provided in the lab. Return the shadow sticks immediately after use so that others may use them.

3. Regarding objectives 6 and 7
Choose a sunny day and a dry spot outdoors. Prop up an earth globe so that Murray, Kentucky is directly on top - facing upward - and so that the north pole is pointing north. You now have your globe oriented with respect to the sun in the same way as the real earth is oriented. Fasten a 3-in. circle of paper over Murray with a tiny piece of Plastick. Using another tiny bit of Plastick, fasten a half toothpick over Murray; this stick must be perpendicular to the globe, that is, along the radius line that comes through Murray on the globe. Hold the paper down with bits of masking tape so wind does not blow it away. Use Plastick sparingly and if it is still useable, return it to the package when you are finished.

With the same materials, though sometimes the paper will not be necessary, make the shadow clocks or determine the location outlined in objectives 6 and 7. Record the times for the shadows. Each shadow clock should contain tracings of at least five shadows.

Attach your shadow clocks in the spaces below:

For Murray

Different longitude but same latitude as Murray

Different latitude but same longitude as Murray

Latitude and longitude both different from Murray

Record below the locations asked for in objective 7. Indicate N or S latitude and E or W longitude. You do not need paper circles for this activity.

Time ________CST or ________CDT

a. Where is the sun directly overhead? _______lat. ________long.

b. Where is the sun to the observer's north? (one location) ________lat.

________long.

c. Where is the sun just coming up. _______long.

d. Where is the sun just setting? _______long.

e. Where is the sun not visible at all today? _______lat. to _______lat.

f. Where is the sun visible all day today? _______lat. to ________lat.

MOD 237 Unifix Cubes Structural Math Material

This MOD is designed to give a working knowledge of mathematical structures using unifix cubes.

OBJECTIVES:

At the conclusion of this MOD you will be able to use unifix cubes in:

1. Numeration
2. Basic operations
3. Areas and volumes
4. Multi-base notation
5. Graphical representations

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Unifix Structural Maths Material, Teacher's Manual
2. Unifix cubes

PROCEDURE:

1. Obtain Color Cube Activities Box from the Resource Center and do activity cards:

   3 - 6
   10 - 15
   16 - 17
   24
   33
   35
   48 (any 10)
   50 (any 10)
   52 (any 10)
   54 (any 10)
   55 - 59
   65 - 70
   10 of your choice from 41 - 130

2. Create some activities using unifix cubes to teach concepts listed in the objectives.

FINAL ASSESSMENT:

1. Bring all worksheets to the evaluation.
2. Be able to demonstrate a working competence relative to the objectives.

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MOD 239 Theory of Numbers III

This MOD is designed to provide additional exercises and experiences with selected topics of theory of numbers.

OBJECTIVES:

At the end of this MOD you will be able to:

1. Identify and determine E-primes.
2. Demonstrate a system for determining the largest counting numbers, L(N), that must be tested in order to determine all the factors of N.
3. Answer selected questions about primes.
4. Explain the role of number-theory problems in teaching mathematics to elementary children.
5. Demonstrate an organizational scheme for mathematical problem solving.
6. Apply the organizational scheme in objective 5 to a new problem.
7. Construct a Pascal's triangle and point out patterns on the triangle.
8. Demonstrate a method of checking arithmetic computations by "casting out nines."
9. Demonstrate the Euclidean Algorithm for determining the GCF for two numbers.
10. Explain the exercises that you have completed.

INSTRUCTIONAL REFERENCES AND MATERIALS:

MMP, Number Theory

INSTRUCTIONS:

From the MMP text, Number Theory, complete the following exercises and keep your work:

Activity 3: Project 1
Activity 4: Project 2
Activity 5: Parts B and C
Activity 7: discuss questions 1, 2, and 3
Activity 8: Parts A, B, C, and D
Activity 9: Parts A and B and Project 4
Activity 11: Project 6
Activity 13: Parts A and B

FINAL ASSESSMENT:

1. Schedule a session with an instructor and bring all work to the session.
2. See objectives.

MODULE 240 MISSING FROM DOCUMENT PRIOR TO ITS BEING SHIPPED TO EDRS FOR FILMING.

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*MOD 241 Protein Synthesis - Self Instructional Module

OBJECTIVES

1. Name three types of RNA and describe their similarities and differences.
2. Explain the composition of ribosomes and their role in protein synthesis.
3. Identify four stages of protein synthesis.
4. Describe the process of charging tRNA and name the components involved; and explain why the fidelity of this process is essential in the accurate translation of genetic information.
5. Describe a polysome and diagram the motions of ribosomes and mRNA in this structure.
6. Diagram (in outline form) the motions of ribosomes, mRNA, tRNA, and amino acids during the steps leading to the addition of one amino acid to a growing polypeptide chain.
7. State the sources of energy for protein synthesis.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on Protein Synthesis.
3. Biology Media instructional materials
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

*MODs 235 and 238 both must be satisfactorily completed before this MOD is attempted.

INTRODUCTION:

The study of protein synthesis is instrumental in understanding how genes are expressed. Genes, or the DNA that forms genes, determine the structures of protein molecules. Proteins in turn serve as the structural components and biological catalysts which determine the shape and metabolic activity of the cell. Protein synthesis, then, is one essential link in the chain of reactions by which genes control all phases of a cell's life,

Protein synthesis is an extremely complex process. Proteins are not made directly from DNA, nor are they made directly by DNA. Instead, DNA forms a model or template from which is made an intermediate compound RNA. There are several different kinds of RNA, each made from a separate region on the DNA. These different kinds of RNA collaborate with one another and with a number of enzymes to produce the enzymes and structural proteins needed by the cell. The purpose of this module is to describe the components and steps involved in the production of proteins in the cell.

OUTLINE:

I. Problems of protein synthesis; requirements for protein synthesis.
    A. Large size of proteins; energy.
    B. Complexity and uniqueness of proteins: information.
II. Structures involved in protein synthesis--RNA molecules.
    A. Messenger RNA.
        1. Function.
        2. Structure--codons
    B. Transfer RNA.
        1. Function.
        2. Structure--anticodons amino acids.
    C. Ribosomal RNA, ribosomes.
        1. Function.
        2. Strucutre--ribosomes.
    D. Other structures.
        1. Enzymes.
        2. Energy sources.
III. Steps of protein synthesis.
    A. tRNA charging.
        1. Specificity: enzymes.
        2. Energy source: ATP.
    B. Initiation.
        1. Steps.
        2. Initial amino acid. and codon.
    C. Elongation.
        1. Steps.
        2. Intermediate: peptidyl-tRNA.
        3. Energy source.
    D. Termination.
        1. Termination codons.
        2. Release factors.
IV. Polysomes.
    A. Description.
    B. Site.
        1. In procaryotes.
        2. In eucaryotes.

PROTEIN SYNTHESIS

① Among all the biochemical compounds present in a cell, proteins as a group are perhaps the most structurally and functionally diverse. Thousands of different proteins catalyze thousands of different chemical reactions. ② Proteins hold membranes together; move parts of the cell, or whole cells, place to place; or keep other parts of the cell, or whole cells, in a fixed position. Considering the diversity of proteins, it probably doesn't surprise you that it takes a complex mechanism to construct them. It probably surprises you more that most proteins are made by just one unique system -- one system which can make any protein to order, according to the disposable set of plans that it is provided.

This module is going to describe the synthesis of proteins: what components are involved, what these components look like, how they work, and where in the cell they work.

Before we talk about the components needed for protein synthesis, though, let's think about what it means to construct a protein...what problems are involved. ③ First, remeber that proteins are very large molecules. Any one protein of average size will contain approximately 4700 atoms connected with covalent bonds. Ofcourse, the structure of a protein can be simplified by considering it to be made of larger subunits -- amino acids, connected in a linear sequence. But still, the average protein has 300 of these subunits and that forms a long and unwieldy chain. Why is size a problem? ④ Well, each of the 299 peptide bonds connecting 300 amino acids together requires energy for its formation. The total amount of energy needed to make a complete protein is quite large.

⑤ There is another problem too. Proteins are not only large, they are complex. And yet, each different protein must have precisely the correct structure. A single incorrect amino acid, an extra amino acid, one missing amino acid can eliminate an enzyme's catalytic activity. Just supplying enough energy will not put the right amino acids together. ⑥ There must also be an input of information for determining the amino acid sequence of each protein as it is constructed. This, of course, is the information of the genes.

Equally important, there must be a reliable system for interpreting this information faithfully, for the information would be useless if the rest of the system made a lot of mistakes.

The complex protein synthesizing system is designed to translate genetic information into amino acid sequences and at the same time apply energy in order to link the amino acids together. In the first part of this module I am going to describe the components of this system and give you a quick look at their roles. As I do this, notice which components are mainly involved with the flow of information, which with the application of energy.

The key compound responsible for protein synthesis in the cell is RNA. ⑦ RNA is a polynucleotide, similar in basic structure to DNA: it contains bases (A, G, C, and U) linked to sugars that are connected by phosphate groups. The detailed three-dimensional structure of an RNA molecule depends on its type and function. ⑧ There are three types of RNA involved in protein synthesis, each with a different function and a somewhat unique structure.

The first type of RNA to consider is messenger RNA (mRNA). ⑨ As its name implies, mRNA carries information from the genes to the site of protein synthesis. The mRNA for any one specific enzyme is made using the gene for that particular enzyme as a template -- thus the RNA carries the information contained in the base sequence of that gene in its own base sequence. When the mRNA arrives at the site of protein synthesis, it then directs the arrangement of amino acids into the proper sequence to form the desired protein. You can see why mRNA is thought of as an agent or messenger for a gene.

How does the messenger RNA carry information? How are the instructions for ordering amino acids arranged or encoded?

⑩ The information of a gene is contained in the linear sequence of its bases. Since the base sequence of a mRNA matches the base sequence of the gene, the information of the gene must also be in the mRNA base sequence. This information is arranged as groups of three bases, called codons. Each codon specifies a single amino acid. When a messenger RNA is "read", it is read codon by codon. At the same time appropriate amino acids are added to a growing polypeptide chain one by one.

The mRNA's function as a linear message ... as a group of codons read in order ... tells us something about its structure. In solution by itself, the mRNA may be looped or bent or rolled in a ball or tied in a knot. Some loops may even be essential for starting the process of protein synthesis. But when the mRNA is directing protein synthesis it must be pretty well unrolled so that its codons can be decoded in the proper sequence. Therefore, we usually think of mRNA as being a long, fairly straight molecule, just as shown in this slide.

The next type of RNA is transfer RNA (tRNA). ⑪ tRNA serves as an adaptor or decoder molecule. Its function is to translate the information contained on the mRNA. Each tRNA has, on one end, a group of three bases called an anticodon. On its other end, the tRNA holds an amino acid. The three bases of the anticodon are complimentary to the three bases for a particular codon on a messenger RNA; ⑫ thus the anticodon can bind to the codon. The amino acid on the tRNA corresponds to that particular codon. ⑬ For instance, one type of tRNA called tRNA$_{trp}$, which carries the amino acid tryptophan, has an anticodon, ACC, that is complimentary to the codon for tryptophan, UGG. Another tRNA, tRNA$_{glu}$, carries the amino acidglutamic acid and has an anticodon, CUU, that is complementary to a codon for glutamic acid, GAA. In general, for each codon that signifies an amino acid, there is a tRNA with a complementary anticodon. ⑭ As a first, crude picture of protein synthesis, you can imagine a group of tRNAs, each tRNA holding its amino acid and lining up along a messenger RNA, fitting its anticodonto the proper codon on the messenger. The amino acids are therefore lined up in the right sequence and they need only be hooked together with peptide bonds.

The structures of the tRNA molecules are quite unusual. ⑮ tRNA, like other RNA, is a single polynucleotide chain; but tRNA contains base sequences that are complementary to each other. This means that regions of the tRNA can double back and hydrogen bond to bases of the same tRNA. Where these hydrogen bonds form there are short areas of double helix much like a DNA double helix. When all these self-complementary regions of a tRNA have formed their hydrogen bonds, the tRNA looks like a mis-shapen clover leaf ... in a flat drawing at least. One of these clover leaf structures is shown on the slide: the amino acid is connected to the base and one end of the RNA chain; the anticodon is in the middle loop. There are some small extra loops or "arms" that vary from tRNA to tRNA. These give each tRNA a little individuality.

⑯ In solution, tRNA molecules probably do not look like clover leaves. No one is certain yet what tRNAs really look like, but one of the ideas is shown on this slide.

The third type of RNA is ribosomal RNA (rRNA). ⑰ Ribosomal RNA is never found alone in the cell. It is always associated with proteins to form ribosomes. Ribosomes are fairly large bodies with molecular weights of around 3 million daltons. ⑱ You have seen them as distinct particles in electron micrographs of cells.

The function and the structure of rRNA is still myterious, but we do know a lot about the function and structure of the whole ribosome. Ribosomes are the machines that hold together and operate all the other components of protein synthesis. ⑲ They bind to tRNAs and to mRNA ⑳ and they also bind to, or contain, various enzymes that form peptide bonds between amino acids and catalyze other steps of the process. One of the functions of ribosomes is to move along mRNA in an orderly manner, matching the tRNA with the proper anticodon to each codon of the mRNA in its turn.

㉑ As you might imagine, since a ribosome is large, it is also complex. Every ribosome has two subunits, a small and a large one. The small subunit binds the mRNA; the large one binds the tRNAs. The small subunit contains a small rRNA and 20 proteins; the large subunit has a large rRNA, a very small rRNA, and about 30 proteins. The actual sizes of the small and large subunits depends on where they were made. In bacteria, blue-green algae, in plastids of plants, and in mitochondria of plants and animals, the ribosomes are relatively small. In the cytoplasm of eucaryotic cells, both plants and animals, the ribosomes are somewhat larger.

㉒ There are other components of the protein synthesizing system that I haven't mentioned yet. Most of these are enzymes: enzymes to hook an amino acid to its corresponding tRNA, enzymes that help the ribosome move along an mRNA yet are not part of the ribosome or mRNA, etc. Also, there are the sources of energy which are so crucial: these are ATP, the common energy carying molecule of the cell, and GTP, which is like ATP except for a guanine (G) base in place of the adenine (A) base.

The next object of this module is to describe the process of protein synthesis: the steps that the mRNAs, tRNAs, and ribosomes perform in order to produce a polypeptide chain. ㉓ Among the steps involved are these: (1) Charging the tRNAs. That is, binding the appropriate amino acids to each tRNA. (2) Initiatong protein synthesis -- combining a ribosome with an mRNA and the first tRNA. (3) Elongating the protein chain -- combining the amino acids, in order, with peptide bonds. (4) Terminating protein synthesis -- releasing the completed protein.

Let's first discuss charging. ㉔ I said earlier that tRNA has the job of finding the correct amino acid and then fitting it to the proper codon in the mRNA, thus assuring the amino acid of its appropriate place in the final polypeptide chain. The process by which tRNA picks up an amino acid is called either tRNA charging or amino acid activation. Enzymes and energy are required to join the amino acid to the tRNA. The enzymes are called amino acid activating enzymes or amino-acyl-tRNA synthetases. ㉕ They provide specificity to the charging reaction. There is a different amino acid activating enzyme for each amino acid. Each amino acid activating enzyme recognizes only its own amino acid and its amino acid's tRNA and links these together. The enzyme forms a covalent, high-energy bond between the amino acid and one end (the 3' end) of the tRNA chain. ㉖ The energy to produce this bond comes in the form of ATP. When the enzyme links the amino acid and tRNA, it at the same time splits ATP into AMP and a pyrophosphate (two combined phosphates) molecule. The splitting of the ATP provides the energy for forming the high-energy bond between amino acid and tRNA. This energy will be used later for forming a peptide bond between this amino acid and another.

To summarize, the charging of tRNA has two functions: (1) to match each amino acid to the proper tRNA and its anticodon; (2) to activate the amino acid -- that is, pump in energy that will eventually be used to connect it to another amino acid with a peptide bond.

Our further explanation of this process will be illustrated by pictures of a cardboard model of protein synthesis. Here are the components used in this model. ㉗ From bottom to top, these are the messenger RNAs, the transfer RNAs, and the amino acids. ㉘ And here are transfer RNAs with the amino acids hooked onto them. ㉙ This is the ribosome, showing the large and small subunits. Let's start synthesizing a protein by charging a mixture of tRNAs with their amino acids.

㉚ The next step is initiation. To start the real process of making a protein, a ribosome must join with an mRNA and an amino acyl tRNA. The ribosome actually binds to the mRNA in two steps: ㉛ first the small subunit binds to the mRNA; ㉜ these two components bind to the first amino acyl tRNA; ㉝ finally the large ribosome subunit binds to complete the group. In bacteria, initiation of a polypeptide chain always begins with an unusual amino acid called N-formylmethionine or fmet for short. This tRNA binds to the codon AUG, so polypeptide chains always start at an AUG base sequence on a messenger. In eucaryotes, the story is much the same, except the amino acid on the initiating tRNA is plain methionine or met, without the formyl. The first codon is still AUG.

The next step in protein synthesis is elongation. Elongation includes all the steps needed to add one amino acid to a peptide chain. The first step ㉞ is to add the next amino acyl tRNA corresponding to the next codon on the mRNA. The next step ㉟ is connecting the first and second amino acids by a peptide bond. An enzyme part of the ribosome forms the peptide bond. It removes the first amino acid (fmet) from its tRNA, and uses the energy stored in the bond between that amino acid and tRNA to form the peptide bond between the first amino acid and the second. The result is a two-amino-acid polypeptide attached to the latest tRNA. This is called a peptidyl-tRNA.

㊱ Next, the ribosome moves along the mRNA to the next codon. Or you might say that the mRNA moves along the ribosome. The peptidyl-tRNA, which sticks to the mRNA, moves with respect to the ribosome too. This opens up the spot on the ribosome for the next aminoacyl tRNA, the one corresponding to the next codon. ㊲ We can add this tRNA; ㊳ the ribosomal enzyme can move the polypeptide chain formed from the first and second amino acids onto the third amino acid, joining them with a peptide bond; ㊴ and the ribosome can move again. As the ribosome moves, the used tRNA that has just lost the peptide chain is released. It goes back to be recharged with another amino acid.

㊵ Each time the ribosome moves, two molecules of GTP are hydrolized to GDP plus one phosphate. The energy released by this hydrolysis is used to push the ribosome along the mRNA.

㊶ To summarize, there is a three step cycle for adding each amino acid to a growing polypeptide chain: (1) add the amino-acyl tRNA; (2) form the new peptide bond between this new amino acid and the amino acid immediately preceding this one; (3) move the ribosome along the mRNA one codon. After each cycle, the ribosome has moved one codon, and the polypeptide chain has grown by one amino acid.
㊷ ㊸

Eventually, ㊹ the ribosome reaches the end of the message, the point where the polypeptide chain has been completed. At this point there is a special codon, UAA, UAG, or UGA. No tRNA has an anticodon that fits any of these codons. Instead, these codons are recognized by special enzymes, ㊺ called release factors. In the presence of one of these termination codons and the appropriate release factor, ㊻ the polypeptide chain (that is, the completed protein) is released from the ribosome. ㊼ Then the ribosome itself falls off the mRNA, ㊽ splits into subunits, and returns to the beginning of a message to start another protein.

What do ribosomes and messenger RNAs look like when they are operating? For one thing, each messenger RNA can be read by more than one ribosome. ㊾ In fact, at the same time that one ribosome is moving along the mRNA, another ribosome may clamp onto the initiation site of the same mRNA and start producing a second polypeptide. As soon as this second ribosome has moved away from the initiation site, a third may follow the second, and so on, until a dozen or more ribosomes are reading a single mRNA strand. It is important to note her that all the ribosomes read the same message alike and therefore produce the same protein. ㊿ When two or more ribosomes are reading the same mRNA, the entire complex is called a polysome. Here is a diagram and here, (51) a picture of polysomes. Polysomes are found in both eucaryotic and procaryotic cells The presence of polysomes in a cell is generally considered an indication that its ribosomes and mRNA are actively working.

Exactly where in the cell does protein synthesis take place? Where are the polysomes? In procaryotic cells the polysomes may be almost anywhere. They may be floating free around the periphery of the cell, but the may also be found in the nuclear area. (52) In fact, here is a picture that shows ribosomes reading mRNA (polysomes) that is still being transcribed from the DNA. This means polysomes are attached to the DNA. Presumably, when these mRNAs are finished, these polysomes can float free into the cytoplasm.

(53) In eucaryotic cells, protein synthesis takes place in the cytoplasm, not in the nucleus. This means the mRNAs (and the tRNAs and the rRNA-ribosomes) must be transported from the nucleus where they are made to the cytoplasm before they can be used. Once these components are in the cytoplasm, they form polysomes. These polysomes can be free, or they can be attached to the membranes (54) of the endoplasmic reticulum. Some biologists now believe that the free polysomes make proteins that are to stay within the cell, while the endoplasmic-reticulum-bound polysomes produce protein for export outside the cell membrane.

In a normal cell, the whole process of protein synthesis is orchestrated beautifully. All components work simultaneiously, so that none are idle and all are used efficiently. They translate many messages at the same time, so that the cell receives a supply of all the different proteins it needs for growth and differentiation. Furthermore, the system is carefully regulated so that specific proteins are synthesized at the times and in just the amounts in which they are needed. The methods of regulation are not entirely understood, but what is known about this fine-tuning of protein synthesis makes another fascinating story. (55)

GLOSSARY

ATP (adenosine triphosphate) -- a cofactor in energy metabolism, containing one base (adenine) and a sugar (ribose) coupled to three phosphates attached in series. Considered a source of energy to drive reactions because hydrolysis of one or two phasphates from ATP releases free energy.

amino acid -- organic compound containing carboxylic acid and amino functional groups. Twenty amino acids are subunits of proteins.

amino acid activation -- the coupling of an amino acid to a tRNA molecule; considered "activation" because the bond between amino acid and the tRNA requires energy to form, and its hydrolysis releases energy. tRNA charging.

amino acid activating enzyme -- the enzyme catalyzing amino acid activation. There is a different enzyme for each amino acid.

amino acyl-tRNA -- a tRNA with its corresponding amino acid attached.

amino acyl-tRNA synthetase -- an amino acid activating enzyme.

anticodon -- a group of three adjacent bases on a tRNA that is complimentary to the codon corresponding to the amino acid of that tRNA.

charging of tRNA -- amino acid activation. Combining a tRNA with its corresponding amino acid. Considered "charging" because it allows the tRNA to participate in further steps of protein synthesis.

codon -- a group of three adjacent bases on mRNA. A unit of information which specifies one amino acid (or termination) in protein synthesis.

complementary -- in nucleic acids, forming a stable base-pair connected by hydrogen bonds. A codon is complimentary to an anticodon if the three bases of one form base-pairs with the three bases of the other.

elongation -- in protein synthesis, the process of lengthening a polypeptide chain by sequential addition of amino acids coded for by an mRNA.

GTP (guanosine triphosphate) -- a cofactor in energy metabolism. Contains one base (guanine) and a sugar (ribose) coupled to three phosphates attached together in series. Considered a source of energy like ATP.

initiation -- in protein synthesis, the first step in the direct translation of an mRNA; the combination of a ribosome with an mRNA and an initiating tRNA.

mRNA (messenger RNA) -- component of the protein synthesizing system specifying the order of amino acids. The RNA formed using as template the gene for a specific protein.

peptide bond -- the bond connecting adjacent amino acid subunits in a protein. A bond formed between a carboxylic acid and an amino group.

peptidyl tRNA -- a tRNA attached to a chain of amino acids, found only as an intermediate structure during the elongation phase of protein synthesis.

polysome (polyribosome) -- a structure consisting of one mRNA and two or more ribosomes in the process of translating the mRNA.

release factor -- a protein that recognizes a termination codon and terminates protein synthesis, leading to the release of the peptide chain from the ribosome-tRNA.

RNA (ribonucleic acid) -- a polymer of ribose-containing nucleotides; a principal material in the protein-synthesizing apparatus.

ribosome -- the largest structure involved in protein synthesis; the structure that binds together all the other components of protein synthesis; a cellular organelle formed from two subunits, each of which is formed from RNA and protein.

rRNA (ribosomal RNA) -- any molecule of RNA incorporated in the basic structure of a ribosome; distinct from mRNA and tRNA.

tRNA (transfer RNA) -- components of the protein synthesizing system that allign amino acids according to the sequence of codons on an mRNA. RNA molecules with anticodons, capable of bonding covalently to amino acids.

termination -- in protein synthesis, the final stage; includes the release of the polypeptide chain from the protein synthesizing apparatus and the detachment of tRNA, mRNA, and ribosome from one another.

MODULE 242 MISSING FROM DOCUMENT PRIOR TO ITS BEING
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MOD 243 Correlating Manipulatives with Mathematics Textbooks

The purpose of this MOD is to allow you to develop a plan for using manipulatives with a textbook-oriented mathematics program.

INTRODUCTION: The following systems in the Western Kentucky area have adopted the Houghton Mifflin Company mathematics series for the period 1977-1982:

Caldwell County
Calloway County
Murray Independent
Carlisle County
Christian County
Daviess County
Fulton County
Fulton Independent
Graves County
Mayfield Independent
Hickman County
Hopkins County
Dawson Springs Independent
Livingston County
Logan County
Russellville Independent
Marshall County
Paducah Independent
Muhlenberg County
Central City Independent
Greenville Independent

Todd County
Trigg County
Union County
Providence Independent

Assume that you are a beginning teacher who has recently been employed by one of the above systems. You will be assigned to a classroom of the grade of your choice, 1-6. Since manipulatives available in your classroom may be limited, you do have accessible all the manipulatives in the Murray State SME Resource Center available for check-out and use.

OBJECTIVES: After you have completed the MOD you will present a list of manipulatives that are available in the SME Resource Center for each unit of the first semester (first half of the text) along with a plan for utilizing the manipulatives in the classroom. The list should include at least five different manipulatives and several games.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Houghton Mifflin Company Elementary Mathematics Textbook series
2. Other elementary math textbooks and teacher's guides in the SME Resource Center
3. Manipulatives and games in the SME Resource Center
4. Guides and resource books for using manipulatives and games in the Resource Center

PROCEDURE:

1. For the grade level you select, review the material in the text, teacher's guide, and supplementary material for the Houghton Mifflin Textbook series.
2. For each unit identify and list appropriate manipulatives and

games for the unit.

3. Write a paragraph-type description for each unit, describing how you plan to use the materials. Include copies of worksheets and handouts if not a part of the Houghton Mifflin materials.

FINAL ASSESSMENT:

Bring the textbook packet and your materials to the assessment session. Be prepared to discuss and defend your plan.

*MOD 244 Regulation of Protein Synthesis: The Operon Hypothesis

OBJECTIVES:

1. Define and distinguish between: repressor, inducer; operon, operator; repression, feedback inhibition.
2. Explain the sequence of events by which an inducer molecule can increase the rate of synthesis of a specific protein.
3. Suggest at least two ways in which one inducer might change the rate of the synthesis of two different enzymes at once.
4. Predict the effects of mutations in various genes of the lactose operon on the regulation of the synthesis of β-galactosidase.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on Regulation of Protein Synthesis: the Operon Hypothesis
3. Biology Media instructional materials
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.
2. Be prepared to discuss the questions listed at the end of this MOD.

*MODs 235 and 238 both must be satisfactorily completed before this MOD is attempted.

INTRODUCTION:

Descriptions of the components and the chemical reactions of protein synthesis and of the translation of the genetic code provide the basis for understanding how genes direct the synthesis of specific proteins, but they do not tell the whole store. Not all genes function all the time and at maximum rate. Instead different genes turn on and off in a well orchestrated sequence to provide controlled patterns of growth and development. *When* a gene directs the synthesis of its protein and how much protein it makes is important.

In a typical bacterial cell, there are certain proteins that occur in large quantities, others that occur in small quantities, and a third group of proteins that appear only at those times and in those quantities at which they are required. Molecular biologists have studied this third group in greatest detail. The best example is a group of enzymes that allows the bacterium *E. coli* to grow on the sugar lactose. The presence of lactose in the growth medium "turns on" the genes that direct the synthesis of the enzymes that degrade lactose to a simpler and more usable sugar, glucose. When lactose is absent or is used up, the genes are "turned off" and the enzymes are not synthetized.

Studies of the effects of lactose on *E. coli* have led to the operon hypothesis, which attemps to explain how the activities of genes can be controlled by compounds, like sugars, inside or outside the cell. The operon hypothesis suggests (a) that the amount of enzyme produced depends on the amount of mRNA made from that enzyme's DNA gene; (b) that the amount of mRNA made from a gene is regulated by a special protein called a *repressor*; and (c) that the ability of a repressor to control mRNA synthesis can be increased or decreased by sugars or other compounds related to the function of the enzyme concerned.

The purpose of this module is (a) to describe the *E. coli* lactose metabolism as an example of regulated gene activity, and (b) to show how the operon hypothesis explains the mechanics of the regulation of gene activity.

OUTLINE:

I. Introduction: Genes are regulated.
  A. Classes of proteins in *E. coli*
  B. REgulation of sugar-metabolism enzymes
II. Operon hypothesis
  A. Transcription and translation of genes
  B. Tenet 1: cell regulates synthesis of mRNA
  C. Tenet 2: repressor and operator control (inhibit) mRNA synthesis
    1. Repressor synthesis
    2. Repressor action
  D. Tenet 3: inducer inactivates repressor.
    1. Repressor binding sites
    2. Inducer action
  E. Review of lactose-metabolism regulation.
III. Conclusions

REGULATION OF PROTEIN SYNTHESIS:
THE OPERON HYPOTHESIS

① Genetic information in DNA can be transcribed onto RNA and used to direct the synthesis of proteins. ② This is the basic process by which genes determine an organism's hereditary traits. However, the formation of RNA and the synthesis of proteins using this RNA does not completely explain the flow of information by which genes determine the shape and character of cells and organisms. There is at least one additional factor needed to insure that genetic information is used properly. This factor is control ... control of the rates at which different genes are used and different proteins are formed. ③ A switching system as complex as that in a power plant must regulate the rates of gene functions.

If all genes worked full out at their maximum rates, you might expect a uniform mixture of all different kinds of proteins, whereas in fact each cell is much more balanced and has a much more specific composition, with certain proteins needed, and found, in higher concentrations than others. To show how carefully a cell controls its composition, I want to describe a bacterium, Escherichia coli. ④ If one chemically analyzes E. coli cells, one finds that their proteins fall roughly into three groups. ⑤ This picture represents the inside of a E. coli cell, and the colored bodies represent groups of proteins. There is one group that occurs in relatively high quantities, like the yellow blobs. Presumably the cells need lots of these proteins. For instance, ribosomal proteins (those proteins that combine with the rRNA to make the ribosomes) constitute ten per cent of the total cell protein. Other enzymes needed for protein synthesis are also present in high quantities. So are enzymes needed for making ATP and enzymes needed for making cell walls.

Another group of proteins occurs in relatively low quantities, like the red squares. In this case, just a few molecules per cell are sufficient to satisfy the cell's requirements. This group includes DNA polymerase (the enzyme that replicates the genome) and other enzymes used for making compounds which are themselves needed in small amounts. The different relative amounts of these two groups of proteins illustrate how different genes are controlled independently. The genes that make ribosomal proteins must work much faster or be turned on more often than the gene that makes DNA polymerase.

The third group of proteins illustrates the principle of gene control even better. In this group, symbolized by green triangles, the quantity of the enzyme present varies with the need of the cells. If the enzyme is needed, it is produced. ⑥ If it is not needed, its production is stopped, and it may even disappear. ⑦ There are many examples of such proteins, but one set of proteins in particular has been extensively studied. We will talk about this set throughout the rest of this module.

This story concerns the sources of carbon and energy that bacteria use for growth. Bacteria often grow on sugars; but not all sugars are equally useful. ⑧ Glucose is the sugar most readily used by these bacteria. If glucaose is present in the growth medium, the bacteria absorb it, using a carrier called *glucose permease* to move the sugar across the cell membrane. The sugar is then directly used for growth, obtaining energy, and for making other small molecules like amino acids. If glucose is not present in the growth medium, but another sugar is, the situation changes. The other sugar must be absorbed and then (usually) converted to glucose before it can be used.

The example I will describe involves the sugar lactose, the main sugar found in milk. ⑨ In order for a bacterium to grow, using lactose as a carbon and energy source, the bacterium must move the lactose through the cell membrane into the cell with a special protein carrier, lactose permease, and then split the lactose into two pieces with an enzyme, *beta-galactosidase*. One of the pieces is glucose. This glucose can be used directly for growth. (The other piece eventually is converted to glucose and used also.) ⑩ The main point is that lactose permease and beta-galactosidase, needed for growth on lactose, are not always present in the cell. They are produced only when the cell grows on lactose. They are hardly produced at all when the cell grows on glucose or on sugars other than glucose or lactose. Apparently the presence of lactose in the medium is a signal that turns on the genes for lactose permease and beta-galactosidase and starts the synthesis of these proteins. ⑪

Lactose is often called the inducer of these proteins, because it induces their synthesis. Genes like these, which can be induced, provide clear examples of gene control that biologists can easily study.

⑫ How are genes regulated? That is, what is the mechanism behind gene control? Unfortunately, we have no general answers. We do not know, for instance, why the genes for ribosomal proteins make more product than the genes for DNA polymerase. However, we do have one specific answer. There is a model mechanism that explains the regulation of the genes in E. coli that make lactose permease and beta-galactosidase. This mechanism was first suggested in a simplified form in 1960 by two French scientists, Francois Jacob and Jaques Monod. ⑬ It is known as the Operon Hypothesis.

In order to describe the Operon Hypothesis, we will use this simplified diagram of an E. coli cell, ⑭ showing the flow of information from gene to protein in the cell. You will recognize the components and the steps of the process in the diagram. The purple area represents the DNA of the cell -- the repository of all genetic information. Messenger RNA is synthesized from the DNA template. The messenger RNA is then used to direct the synthesis of proteins by ribosomes, transfer RNA, and the other components involved in protein synthesis, all working together as polysomes. Note that messenger RNAs break down rather quickly in bacteria. Each one lasts only one to five minutes. Therefore, mRNAs must be continually synthesized to maintain a supply for protein synthesis. Once synthesized, the proteins wrap themselves up in specific three-dimensional conformations and become functional enzymes, carriers, and other cell components. So far, this overall picture mentions nothing about controling the rate at which genes make messenger RNA, or polysomes make proteins.

⑮ Now let's consider the same cell, but looking specifically at the genes which make lactose permease and beta-galactosidase. These particular genes are positioned together on the DNA, and they actually produce one messenger RNA. That is, one single length of RNA is transcribed from the DNA containing these two genes and thus carries the information from both the genes in its base sequences. We should redraw this picture, ⑯ showing the single messenger RNA. The fact that both these genes are transcribed onto one messenger does not prevent them from making their different individual proteins, but it does make them a functional unit in at least one respect. As you will see, it allows them to be controlled together to produce protein or not produce protein at the same time in response to the same stimulus. This sort of functional unit -- one or more genes controlled by one stimulus -- is called an operon. ⑰ The genes we are talking about form the lactose operon.

That brings us to the Operon Hypothesis: a description of the mechanism behind the regulation of the lactose operon.

⑱ The first tenet of the operon hypothesis states that gene expression (or the synthesis of proteins) is controlled by regulating the synthesis of messenger RNA. ⑲ If a gene is actively used as a template for mRNA synthesis, its proteins will be produced from the mRNA. ⑳ If a gene cannot be used as a template for mRNA synthesis, its proteins will not be produced. One could imagine as an alternative possibility that a cell could control a gene by regulating the use of its mRNA rather than the synthesis of its mRNA. By stipulating that the synthesis of messenger RNA is regulated, we know that we must look directly at the DNA for the mechanism of regulation.

㉑ Here is a series of pictures showing synthesis of messenger RNA using as a template the DNA containing the genes for beta-galactosidase and lactose permease, represented by the letters Z and Y. The enzyme RNA polymerase binds to the DNA at a region of the DNA called the promoter. ㉒ The promoter for the lactose operon is to the left of gene Z. Once the enzyme binds to the promoter, it moves to the right along the DNA, synthesizing an RNA strand. ㉓ The first part of this RNA will carry the base sequence of gene Z; the next length of RNA will carry the base sequence of gene Y. According to the first tenet of the operon hypothesis, once this DNA is synthesized it can be used as a messenger for the production of beta-galactosidase and lactose permease.

㉔ The next tenet of the operon hypothesis states that there is a molecule called the repressor, which can bind to a region of DNA called the operator. ㉕ The operator lies between the promoter and the Z gene. ㉖ When the repressor binds to the operator, it prevents the RNA polymerase from transcribing either gene Z or gene Y.

What is a repressor, and where does it come from? ㉗ The repressor is itself a protein, coded for by its own gene (gene i). As far as we know, this gene always works, so there are always a few molecules of repressor in the cell. The repressor for this lactose operon is specific -- it binds only to this operator: it works only on this operon.

㉘ Exactly how does the repressor prevent the transcription of the genes in this operon? There are two possible ways: first, the bulky repressor attached to the operator lies very near the promoter, and it may by its sheer size prevent the RNA polymerase from reaching the nearby promoter. Second, the operator-bound repressor lies between the promoter and genes Z and Y. It may prevent the RNA polymerase from moving along the DNA even if the polymerase does succeed in reaching the promoter.

The action of the repressor shows how these genes can be turned off. From what I have said so far, you might guess that they are always turned off. Now, how can they be turned on, and turned on specifically in the presence of lactose?

㉙ The third tenet of the operon hypothesis (which explains how these genes are turned on) states that the inducer inactivates the repressor. The inducer, you remember, is lactose -- it induces the synthesis of the enzymes. When we say that lactose inactivates the repressor, we mean that is prevents the repressor from binding to the operator. It can do this because the repressor is a protein with the complex and specific three-dimensional structure of a protein and with the binding sites that only occur in proteins. ㉚ The repressor in fact has two binding sites; one for the operator and one for lactose, the inducer. The shape of the repressor and of its binding sites depends on the presence or absence of lactose. ㉛ In the absence of lactose, the operator-binding site has the correct shape to bind firmly to the operator. ㉜ The presence of lactose on the lactose-binding site changes the shape of the entire repressor protein, and in particular it changes the shape of the operator-binding site. The repressor thus loses its ability to bind to the operator.

㉝ When lactose is present in the growth medium, it enters the cell and binds to the lactose repressor. This prevents the binding of the repressor to the operator. It may even remove a repressor already bound to an operator. This in turn allows RNA polymerase to attach to the lactose operon promoter and to transcribe the Z and Y genes onto messenger RNA. This finally results in the synthesis of lactose permease and beta-galactosidase. Thus we see how lactose, the inducer, can turn on these specific genes and induce the synthesis of these particular proteins.

To conclude the story of lactose and see how gene regulation in this case contributes to the workings of the cell, let's consider for a minute the life of an E. coli bacterium. E. coli lives in the lower intestine of man and other organisms. ㉞ At first, growing in a digestive tract the contents of which contain glucose (or another sugar) but not lactose, the bacterium would not want to waste energy or other resources on synthesizing useless lactose permease and beta-galactosidase. In this situation, the cell's lactose repressor would bind firmly to the lactose operator. These genes would be almost completely turned off and very little lactose permease or beta-galactosidase would be formed.

㉟ If the host organism then ingested some lactose, it would be to the bacterium's advantage to manufacture lactose permease and beta-galactosidase in order to utilize the new food source. ㊱ At this time, a small amount of lactose would enter the cell (using a residual permease present all the time) and bind to the repressor. ㊲ The repressor would fall off (or not bind to) the operator; RNA polymerase would transcribe the genes of this operon; and lactose permease and beta-galactosidase would be formed. The lactose permease would carry more lactose into the cell and the beta-galactosidase would convert the lactose to glucose for growth.

㊳ Eventually, the lactose in the intestine would be used up, and the carrier and enzyme would no longer be useful. When no more lactose could be taken up, and when all the lactose in the cell was broken down by beta-galactosidase, the lactose bound to the repressor would also be used. (It is bound firmly, but not permanently, to the repressor.) ㊴ Then the repressor would retrun to the operator and synthesis of mRNA from this operon would cease. Because existing messenger RNA continually breaks down (in 1 to 5 minutes), ㊵ the synthesis of lactose permease and beta-galactosidase soon also would stop. Eventually, ㊶ the existing carriers and enzymes would break down or be diluted out in the growing cell population.

The Operon Hypothesis was first suggested in 1960. It took many years before it was accepted as the explanation for the regulation of the lactose operon. Even now, it can only be considered true for this one set of genes. Other operons are regulated, but the mechanism behind the regulation may be different. Many researchers are currently investigating the question of how much and in what ways the mechanisms of regulation of other genes in other organisms resemble the one just described.

The control of genes is extremely important not only in bacteria, but also in the more complex eucaryotic organisms. One of the special tricks of eucaryotes is their ability to form specialized cells and tissues to handle special functions. This is differentiation. The formation of specialized cells involves the synthesis of special proteins: ㊷ red blood cells, for instance, are packed with the protein hemoglobin; ㊸ muscle cells, with the contractile protein actomyosin. This synthesis of different proteins in different cells indicates a regulation of the genes involved. The mechanism of regulation of genes in eucaryotes will probably be different from that proposed by the Operon Hypothesis. But even with eucaryotes, the Operon Hypothesis has provided a valuable framework of ideas from which to study the regulation of genes. ㊹

GLOSSARY

beta (β)-galactosidase -- an enzyme that catalyzes the breakdown of lactose by hydrolysis to form the products glucose and galactose.

carrier -- a specialized protein that promotes the movement of a large or polar molecule across a biological membrane. There is a different carrier for each type of molecule to be moved. A permease.

genome -- the collection of genes on the DNA.

glucose -- a simple sugar with the formula $C_6H_{12}O_6$, the primary substrate of glycolytic respiration and thus the prime source of carbon and energy for fueling the metabolism of the cell.

inducer -- a molecule that promotes the synthesis of an enzyme or set of enzymes. In general, inducers are relatively small or simple molecules like sugars or amino acids, rather than large molecules like proteins. Lactose is the inducer of the lactose operon.

lactose -- the most abundant sugar in milk; consists of two simpler sugars, glucose and galactose, connected together by covalent bonds.

lactose operon -- the set of genes, adjacent to one another on the *E. coli* genome, which are regulated by lactose, the lactose repressor, and the lactose operator. Includes a promoter, and operator, and the structural genes for beta-galactosidase, lactose permease, and galactoside acetylase.

operator -- a set of genes, normally adjacent on a genome, which are controlled as a single unit, together with the regions of DNA involved in the control (promoter and operator).

Operon Hypothesis -- the model by which Jacob and Monod explained the regulation of lactose metabolism; postulates the organization of structural genes into a unit (operon), and postulates the existence and functions of a promoter, operator, repressor, and inducer.

permease -- a carrier protein. Promotes movement (permeation) of a molecule across a membrane.

promoter -- the region of DNA that initially binds to RNA polymerase. The region of DNA at which transcription begins.

repressor -- a protein that binds to a special region of DNA (an operator) and inhibits the transcription of nearby structural genes.

RNA polymerase -- the enzyme responsible for the synthesis of RNA, using DNA as a template and ribonucleoside triphosphates as substrates.

transcribe -- to synthesize RNA. A gene is "transcribed" when it is used as a template for RNA synthesis.

MOD 245 Developing a Teaching Unit in Science

OBJECTIVES:

At the completion you will have compiled a plan to teach an ESS unit to a class at the grade level of your choice.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. ESS Teacher's Guides
2. The McGraw-Hill Evaluation Program for ESS in Resource Center
3. References and materials in the SME Resource Center

PROCEDURES:

1. Identify the grade level of your choice.
2. Select one of the ESS units appropriate for the grade level you have chosen.
3. Write objectives for the unit.
4. Develop a plan for introducing the unit.
5. Select appropriate activities for accomplishing your objectives. (These may come from the ESS unit or some other source.)
6. Develop an evaluation plan for evaluating the accomplishing of the objectives.
7. Identify a set of materials needed for the unit.
8. Estimate the amount of time needed to complete the unit.
9. Prepare, in good form, preferably typed, your plan. You may use the following format:

    Title
    Grade Level
    Approximate Time Required
    Materials and Equipment Needed
    References
    New Vocabulary (Optional)
    Objectives
    Introduction
    Activities
    Evaluation

FINAL ASSESSMENT:

Present to the instructor, in good form, a copy of your plan. Revise the plan until both agree that it is a complete plan of good quality.

MOD 246 Self-Directed MOD

This MOD is designed to allow you to pursue a topic of your own choice in order to enhance your competency in math, science, or the teaching of math and/or science.

OBJECTIVES:

The objectives will be determined by you.

INSTRUCTIONAL REFERENCES AND MATERIALS:

References needed will vary. The staff will assist in identifying references if needed.

PROCEDURES:

Outline, in writing, what you wish to accomplish and a plan for assessing the outcome. Get this approved by a member of the staff before you undertake the MOD.

FINAL ASSESSMENT:

The final assessment plan will be designed by you and approved by a staff member before the MOD is undertaken.

MOD 247 Rocks and Minerals
Observing, classifying, and communicating

PREREQUISITES: MOD 106, "Classifying," read the "Introduction" in ESS, Rocks and Charts, Teacher's Guide

OBJECTIVES:

Given 18 different samples of identified rocks and minerals, you will choose 10 of these specimens and classify them by writing an identification key similar to the one on page 2 of MOD 106.

You will be able to give a positive identification to at least eight of the rocks you have studied and/or classified. (To a great extent, this can be done by using the photos in the books by Chesterman, Sorrell, Zim, Arem, and Pough.)

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. ESS, Rocks and Charts, Teacher's Guide
2. Helfer, How to Know the Rocks and Minerals
3. Rocks for ESS, Rocks and Charts
4. Magnifier, streak plate, iron-steel nail, copper sample, balance scale, steel knife, container for water, magnet, vinegar
5. Rocks and Minerals, Joel Arem
6. Rocks and Minerals, Zim/Shaffer
7. A Field Guide to Rocks and Minerals, Pough
8. A Field Guide to North American Rocks and Minerals, Chesterman
9. Minerals of the World, Sorrell

FINAL ASSESSMENT:

Present your key to the instructor. Your success in this MOD will depend on how easily the instructor can identify a rock specimen by using your classification key. Be sure to take the rocks you have chosen for identification with you to the evaluation session.

The following rock samples are found in the MOD tray.

Biotite
Calcite
Feldspar, pink
Galena
Graphite
Gypsum

Hematite
Halite
Limestone
Magnetite
Fluorite
Granite

Obsidian
Quartz, milky
Sandstone, gray
Talc
Pyrite
Siltstone

PROCEDURE:

Of the 18 different samples of rocks and minerals in the MOD tray, classify 10 of them. Use the identification key found in the MOD tray.

Because a particular type of rock may have many different colors and sizes, avoid using these characteristics in describing the whole rock. However, the color of a streak caused by rubbing the rock on a piece of unglazed porcelain is a feature that may be used to classify a rock. See the references for further explanation.

Your instructor will have a test kit containing the same types of rocks and minerals that are included in the MOD tray. Your success in this MOD will depend on how easily the instructor can identify a rock specimen from the test kit by using your classification key.

In making your identification key do not get bogged down by the specific characteristics as outlined in MOD 106, but use those relevant to these specimens.

MOD 248 Temperature and Solutions
Communicating, predicting

OBJECTIVES:

1. Given a solute with water at various temperatures, you will observe, record, and graph the relationship between temperature of a solvent and dissolving time.
2. Given the data obtained in connection with objective 1, you will predict dissolving time for intermediate temperatures and then make measurements to test your predictions.
3. You will dissolve sodium hydroxide and sodium thiosulfate in two separate containers of water and observe and record the results carefully.
4. You will carefully formulate at least two questions related to the phenomena you observed in this MOD, and you will seek out the answer to at least one of these questions.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA, 73, Solutions, p. 5 and Worksheet, "Temperature and Dissolving Time"
2. SCIS, Energy Sources, Teacher's Guide, Chapter 18
3. General chemistry and physical science texts
4. Hot plate, glass containers, test tubes, thermometer, sugar, salt, potassium nitrate, seltzer tablets, solid sodium hydroxide, sodium thiosulfate crystals, graph paper

FINAL ASSESSMENT:

Present to and discuss with the instructor your written records corresponding to the objectives above.

PROCEDURE:

1. **Read SAPA,** 73 , "Temperature and Dissolving Time," & Activity 1, p. 5. Carry **out the activities described there including:**
   a. **observing, recording, and graphing the relationship between dissolving time and temperature of the solvent;**
   b. **predicting the dissolving time for intermediate temperatures and measuring in order to test your prediction.**

   Record your results in the space below.

NOTE: To accomplish objectives 1 and 2, you may need to collect data for several temperatures in addition to 20°C and 40°C.

2. In a test tube half full of water at room temperature, dissolve two pellets of sodium hydroxide and carefully notice the temperature change. Do the same in another test tube with a level teaspoon of sodium thiosulfate crystals. Record your observations:

3, Formulate at least two questions related to the phenomena you observed in this MOD and find an answer for at least one of your questions. You may wish to use the general chemistry and physical science books on the shelf in the Resource Center.

MOD 249 Flexibility MOD

This MOD-slot is retained to allow flexibility in the program. It is provided to allow the staff to integrate unique occurrences into the program, should they arise.

MOD 250 Use of Water by Plants
Measuring, inferring

OBJECTIVES:

1. Using the potted plants provided, you will determine the approximate amount of water utilized per day by the plants for the process of transpiration.
2. By manipulating various variables, you will be able to determine the effects of these variables on the rates of transpiration.
3. By measuring the leaf surface area, you will be able to determine the weight of water lost per square centimeter of leaf surface area per 24-hr. day. Assume that transpiration occurs from the bottom of the leaf only.
4. Formulate plausible inferences to explain the results obtained in activities 1 through 5.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Two potted plants
2. Various botany and general biology texts
3. Balances, aluminum foil, plastic bags, lamp, mercury thermometer
4. SAPA 52, Plants Transpire

FINAL ASSESSMENT:

See objectives above.

PROCEDURE:

1. Controls

   A. Obtain two potted plants from the instructor. These plants are growing in the same kind of soil, the same kind of pot and are approximately the same size and age.
   B. Wrap each pot in two layers of aluminum foil, and be sure there are no leaks in the foil. The aluminum foil should be cut so that it will fold over the top of the pot and completely cover the soil with the plant stem only emerging through the foil.
   C. Weigh each plant on the large gram balance. Record in the chart provided the combined weight of each pot and plant to the nearest gram.
   D. Give each plant 20 grams of water. This is done by pouring enough water on the soil to increase the weight by 20 grams.
   E. Set the plants on the window sill of the Lab for 24 hours. Select a spot that receives sunlight in the daytime.
   F. Weigh the pots and plants after 24 hours and record the weights.

2. Variables of light and darkness

   A. Place each plant on the balance and add enough water to make it weigh as much as it did in activity 1(D) above.
   B. Place the plants on the window sill for 24 hours. One of the plants will be covered with a paper box so that it will not receive any light.
   C. After 24 hours weigh the pots and plants and record the weights.

3. Plastic bag treatment

   A. Place each plant on the balance and again add enough water to bring it up to the weight recorded in activity 1(D) above.
   B. Place one plant in a large clear plastic bag. The bag should be supported with sticks so that it does not rest on the plant. The bag should be just large enough to nicely cover the pot and plant but not much bigger. The other plant will serve as a control and should be set alongside the plant covered with a bag.
   C. After 24 hours weigh the plants. Weigh the plastic-covered plant with the bag in place and after you remove the bag.

4. Bright light and heat treatment

   A. Weigh the plants and again add water to bring them up to the weights recorded in activity 1(D) above.
   B. Place the plants on a laboratory desk in the Lab. Obtain a desk lamp and place it between the two plants. Turn the reflector so that it shines on one plant only, and keep the plant about 1 foot from the light bulb. After the lamp has been on for about 15 minutes, measure the temperature in the center of the plant area. This is done by placing the bulb of the mercury thermometer in the center of the leaf area.
   C. Keep the plants in this position for 24 hours. Weigh the pots and plants and record the weights.

5. Measurement of leaf surface area

A. Draw accurately a square 10 centimeters on a side on a piece of ordinary writing paper. Cut out the square.

B. For each plant, outline all its leaves on the same kind of paper. This can be done so that you closely approximate the sizes and shapes. Cut out the drawn leaves of each plant. Place the "paper leaves" in an envelope and bring them to the evaluation. How can you use these materials to attain objective 3?

Activity	Plant A (Untreated)		Plant B (Modified)	
	Weight of Pot and Plant		Weight of Pot and Plant	
	Initial Weight with 20 gm. water added	Weight after 24 hours	Initial Weight with 20 gm. water added	Weight after 24 hours
1				
2				
3				
4				

MOD :50

MOD 251 Analysis of Straight Lines

This MOD is concerned with the basic concepts of analysis of the straight line.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Observe occurrences and uses of straight lines in the real world.
2. Analyze lines.
3. Apply the analysis to real-world porblems.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Analysis of Shapes
2. MMP slide/tape, "Analysis of Shapes"
3. Current elementary school mathematics textbook series
4. Straightedge, compass, graph paper, globe

OBTAIN ALL THESE MATERIALS IN THE RESOURCE CENTER BUT FOR THE GRAPH PAPER

PROCEDURE:

1. View the MMP slide/tape, "Analysis of Shapes."
2. In MMP, Analysis of Shapes, do
   Activities 1: Items 1, 3, 5, and 7
   2: Items 1, 2, 3, 4, and 5
   3: Items 1, 2, 3, 4, 5, and 6
   4: Items 1, 2, 3, 4, and 5
   5: Items 1, 2, 3, 4, 5, 6, and 7
   6: Items 1, 2, 3, and 6
3. Prepare a construction activity for elementary students from what you have learned in this MOD.

FINAL ASSESSMENT:

1. Bring all your work sheets and the activity to the evaluation.
2. Be able to answer questions that were proposed in various activities.
3. Be able to perform constructions similar to ones done on work sheets.

MOD 252 The Sun as a Celestial Object
A Self Instructional MOD

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Explain general characteristics of the sun, such as size, mass, and temperature.
2. Discuss the energy source of the sun.
3. Discuss and explain how the sun is the major source of gravitation in the solar system; how it rotates; and the cycle of sunspot activity.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Our Planet in Space by Navarra and Strahler, all of Chapter 3, second section of the book, starting on p. 43
2. Astronomy One by Hynek and Appel, Chapter 14
3. Exploration of the Universe by Abell, Chapter 17
4. A Star Called the Sun by Gamaw, Chapter 1
5. The film, Our Mr. Sun
6. The slide-set on the sun, slides 1 through 20

PROCEDURES:

Read pages 2 and 3 of this MOD.
Chapter 1 of A Star Called the Sun,
Chapter 14 of Astronomy One,
Chapter 17 of Exploration of the Universe,
Chapter 3 (Section 2) of Our Planet in Space.
There will be some repetition in these readings, but they, altogether, will give you a good introduction to the sun as a celestial object.

View the sun slides, 1-20.

View the film, Our Mr. Sun.

Concentrate on the questions which you have been asked to formulate answers for.
Answer the self-help questions.

FINAL ASSESSMENT:

Arrange an evaluation with the instructor and be prepared to discuss any points covered in the objectives.

The sun was very likely the first celestial object you saw. At that time, you probably did not think much about it. Later, you grew to appreciate it on winter days, and to avoid too much of it during summer. The sun is a star; very similar to most of the other stars we so often see, only much closer to us. Consequently, we know more about it than the other stars. There are three major reasons for studying the sun as a celestial body. 1) It is the major, and almost only, energy source in the solar system. 2) Its mass gravitationally controls the movements and positions of all the other objects in the solar syster. 3) It is a star, and as such, supplies us with a very close specimen to study, and thus learn a great deal about stars in general.

We have learned the mass, temperature, size, composition, age, energy source and output, evolutionary stage, and future destiny of the sun. A more elaborate discussion of any or all these will be found in the readings suggested, or can be had by discussion with Professor Burnley.

The sun is composed of more than 75% hydrogen and more than 20% helium. The remaining 3 or 4% is made up of some 65 or so of the heavier elements. Altogether, it has yielded some secrets about itself and the stars in general, but it has given us about as many new questions as answers to old ones. Why does it rotate differentially? What are the sunspots and why do they occur? How could there have formed at least four fairly massive globules of high density materials to be expelled from the solar interior, i.e. the Terrestrial Planets?

Following are some questions that you should try to formulate the answers to.

1. Why does the sun not fall inwards upon itself, i.e. collapse, or not explode?

2. As the energy it is giving off is the result of chain reactions of hydrogen fusion, why does it not suddenly fuse in one big blast?

3. What are the sunspots? i.e. are they sources of energy release via convection, etc.?

A list of self-help questions follows. Answers can be found in the film and from the readings.

1. What is the diameter of the sun?

2. How far away is the sun? Average, Aphelian, Perihelian?

3. What is the approximate age of the sun?

4. What is the period of rotation for different parts of the sun?

5. Name the layers of the solar atmosphere.

6. What is the sun mostly composed of?

7. Define flares, prominences, and spicules.

8. What is the energy source of the sun?

9. What type of thermonuclear activity is going on in the sun?

10. What is the approximate mass of the sun, in earth masses?

11. What are the approximate surface and interior temperatures of the sun?

12. What do Wein's Law and the Stefan-Boltzman Law tell us about the sun?

MOD 253 An Inquiry Lesson From ESS: Bones (Group Activity)

OBJECTIVES:

1. Assembled in small groups of four and without the aid of any references, you will estimate the number of bones you have in your left arm (shoulder to fingers).
2. Given a disarticulated cat skeleton, your group will classify the bones according to what you believe should be in the following categories: head, arms and fingers, legs and toes, backbone and rib cage, hips, and shoulders.
3. Using your own bodies as a reference, your group will assemble the disarticulated bones into a cat skeleton.
4. After assembling the cat skeleton, your group will compare its assembled skeleton with an articulated cat skeleton and will make the necessary corrections.
5. Given a mystery bone, your group will try to identify the mystery bone by referring to the cat skeleton.
6. Given the experiences described in objectives 1 through 5 you will be able to discuss the ways in which this MOD exemplifies the philosophy and approach of ESS.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Bones, Teacher's Guide
2. ESS, How to Make a Chicken Skeleton
3. Disarticulated cat skeleton in Resource Center
4. Articulated cat skeleton in Resource Center
5. Yourself
6. Mystery bones

FINAL ASSESSMENT:

See objectives above. Activities corresponding to objectives 1 through 5 will be assessed during a large-group activity in the laboratory. Objective 6 will be evaluated individually during a scheduled period with the instructor.

MOD 254 Analysis of Triangles I

This MOD is concerned with the basic concepts of analysis of the triangle.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Observe occurrences and uses of triangles in the real world.
2. Analyze triangles.
3. Apply the analysis to real world problems.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Analysis of Shapes
2. Current elementary school mathematics textbook series
3. Paper, ruler, scissors, construction paper, brads, compass, graph paper, metric ruler, and protractor

PROCEDURE:

1. In MMP, Analysis of Shapes, do
   Activities 7: Items 1a, c, d; 2; 3a, b, c; 4
   8: Items 1, 2, 3, and 4
   9: Items 1, 2, 3, and 6
   10: Items 1, 2, 3, 4, and 5
   15: Items 1, 3, 4, and 6
2. Prepare a game or an activity for use in teaching the concepts learned in 1 to elementary school students.

FINAL ASSESSMENT:

1. Bring all your work sheets and the game or activity to the evaluation.
2. Take a written test in conjunction with the oral evaluation.

MOD 255 Oceanography
Observing, Inferring, Analyzing

OBJECTIVES:

After completing the suggested viewings, readings, and experiments you will:

1. Be able to plot the major currents and "streams" that circulate within the oceans of the earth.
2. Explain "continental shelf" and "continental slope."
3. Predict how the oceans might help bail us out of the energy bind, with regards to both energy sources and minerals.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Oceanography--A Study of Inner Space, W. Yasso
2. Biology--Patterns in Living Things, Morholt and Brandwein
3. Investigating Earth, ESCP
4. Our Planet in Space, Navarra and Strahler
5. The film, The Boundless Seas
6. Introduction to Physical Oceanography, W. S. Von Arx

PROCEDURES:

1. Read the following:
    A. Oceanography by Yasso, Chapter Three
    B. Biology by Morholt and Brandwein, Chapter Five
    C. Investigating Earth by ESCP, Chapter Ten
    D. Our Planet in Space by Navarra and Strahler, Chapter Twenty-three, "Rifting of Ocean Basins and Continents," pp. 489-506, in the second part of the book. Perform the experiment on p. 498.
2. View the film, The Boundless Seas. Some of the questions are based on the film. If you can not answer some of them, you may want to view the film a second time.
3. Answer the list of questions at the end of the MOD.
4. Make up a chart or map, showing the following major currents and underwater mountain ranges on a sketched world map. You need to show only the outline of the continents. This can be done on an 8 x 11 sheet of paper or larger if you desire. Most of these can be found in Oceanography by Yasso and in Introduction to Oceanography by Von Arx, pp. 174-75.

Gulf Stream
North Atlantic Current (or Drift)
Brazil Current
South Equatorial Current (Atlantic)
South Equatorial Current (Indian)

The major mountain ranges in the Atlantic and Pacific Oceans (one in each)

Kurashio Current, North Pacific, and California Currents
East & West Australian Currents
North & South Equatorial Currents (Pacific)

The Sargasso Sea

QUESTIONS:

1. What approximate percent of the surface of the earth is covered with water?
2. Why do we say water is unique to this planet?
3. What else seems to be unique to earth?
4. What is the ocean floor like?
5. Where is the greatest mountain range in the ocean?
6. What is a rift?
7. Where has an island been formed in recent times? By what means?
8. What is a plate?
9. What is a coral reef? Where are many of them found?
10. What is the Gulf Stream? Why does Iceland enjoy a moderate climate?
11. Name three other currents of some degree of prominence.
12. Does water move with wave motion?
13. Describe (water) wave motion.
14. What is a hurricane?
15. What is a tsunami? What causes one?
16. What causes the tides?
17. What are some of the materials we get from the sea?
18. Comment on the statement, "All life is dependent on the sea."
19. What is the Continental Shelf? Slope?
20. What is kelp?
21. Define phyto plankton.
22. Why does so much of the life in the sea exist in the area that is penetrated by light?
23. What is a migration? Example?
24. Name two sea mammals.
25. Approximately how deep is the deepest part of the ocean floor?
26. Where is this located? What is this called?
27. What are nodules?
28. What is presently being mined from the ocean floor?

FINAL ASSESSMENT:

Bring your chart with you to the evaluation session and be prepared to answer any of the above questions.

MOD 256 Observing Mold Gardens
Controlling variables, experimenting

OBJECTIVES:

1. You will be able to select at least six kinds of media, that is, substances, from your everyday environment that will support the growth of at least six different kinds of molds.
2. You will be able to name at least three media you have tested that do not allow molds to grow on them. You will be able to discuss with the instructor your evidence for believing that these substances do not support the growth of molds.
3. After growing 4 different kinds of molds, you will be able to name at least two characteristics of each mold that distinguish that mold from another.
4. After properly planning your experimentation, you will be able to name at least three environmental conditions necessary for the growth of molds, and you will show the experimental evidence that supports your statements.
5. You will be able to name the variables held constant, the manipulated variable(s), and the responding variable(s) in your experimentation on growing molds.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. SAPA 28, Molds and Green Plants
2. ESS Filmloops: Rhizopus and Penicillium
3. ESS, Micro-Gardening, Teacher's Guide
4. Media: substances of the students' choice on which mold may by grown
5. Mold-growing dishes (with caps if desired), magnifiers, compound and dissecting microscopes, slides, cover slips, medicine droppers

FINAL ASSESSMENT:

See objectives above. Bring all experimental materials and data to your instructor. The evaluation should be scheduled as soon as possible after you complete the activities.

PROCEDURE:

General Information:

Molds are saprophytic organisms, that is, organisms that require organic materials as a food source. They are not able to make their own organic materials from carbon dioxide, water, and the sun's energy as the plants do. From the above criterion it is evident that molds must grow on other living substances, substances produced by living organisms, or on organisms that have died. Molds are important organisms that function in the cyclic decomposition processes seen everywhere in nature.

Molds can be characterized as single-celled organisms that have reached a high degree of colonization, that is, they form clusters of cells living together. Many molds live as individual cells; this is seen in some yeasts. Other molds grow as strings of cells attached end to end. In this case, we say that molds grow in mycelial form with each strand of cells being a mycelium. Most of the molds that you will see in this experiment will be of the mycelial type. The colors, textures, shapes, and sizes of the clusters of mycelia, called colonies, are used in identifying the molds.

Often the mycelia of molds are colorless and are hard to see. Very often, when we eat bread we also eat mold mycelia that are growing within the bread matrix. It is not until the mold takes on a color that we can see it and realize that the bread has a mold on it. The color change is usually related to the reproductive process of the molds.

Where do molds come from, or how does something become contaminated with molds? All of nature is contaminated with mold spores. These can be defined as dormant single-celled stages that will grow and divide into mycelial strands if they are placed in an appropriate environment. The proper environment may require moisture, a correct temperature, light or darkness, proper food nutrients, etc. A mold spore may fall upon a food source of organic materials, but it will not grow because the food source does not contain all the required nutrients for that particular kind of mold. Another kind of mold spore may land on the same food source and grow because all the requirements are available for that mold. However, it is not only the available nutrients that can determine whether or not a mold can grow on a particular substance. Bread mold, for example, will not grow on an orange because the orange is too acidic for the bread mold.

Usually, mold spores are so small that they can easily become air-borne, and it is in this manner that most things get contaminated with spores. Opening a loaf of bread and removing a slice will usually result in an in-rush of air to replace the bread slice. The loaf is then very probably contaminated with mold.

If mold mycelial growth begins with a spore, then the mycelia must necessarily produce spores in order to propagate the species. This is simply accomplished because there are many divisions of the nucleus in a cell of the mycelium. Each new nucleus that is formed is surrounded by a small amount of cytoplasm and is called a spore. When such a dividing cell is full of spores it ruptures and the spores are free to be air-borne and disseminated. A mycelial cell laden with spores is often colored. Many such cells in the colony can then affect an overall change in the color characteristic of the mold. For example, when bread mold appears green, the mold is in the process of spore formation.

Activities:

1. After reading background materials, you should select a variety of media that you suspect will or will not support mold growth. References that will help you are: this MOD, pp. 2-3, SAPA 28, Molds and Green Plants, ESS Film-loops, Rhizopus & Penicillium and parts of ESS, Micro-Gardening, Teacher's Guide.

2. Plan your experiments so that you can control and determine the variables involved. For example, some questions you may want to raise are: Do molds grow with or without water? Do molds need light? Do they grow better in the dark? Do they need air? Will they grow in the cold? How much heat can they stand? Etc.

3. Use the mold cups provided in the MOD tray. Covers are available if you wish to use them.

4. Observe your media for a period of at least ten days and take notes each day.

5. Some hints:
   a. You may want to allow for only air contamination of your media.
   b. You may want to contaminate your media with other things, for example, pondwater, soil, dust from the room, etc.
   c. You may want to take some mold from one medium and see if it will grow on another medium.

6. Sometime during the experiment, you should take some mold mycelia and place it on a slide in a drop of water. Observe it under the compound microscope. Can you see the spores?

7. All mold colonies should be viewed with the stereomicroscope.

MOD 257 Analysis of Triangles II

This MOD is concerned with the analysis of triangles by angles and relationships of angles and sides.

OBJECTIVES:

At the conclusion of this MOD you will be able to:
1. Determine which combination of angles can be angles of triangles.
2. Analyze relationships between sides and angles of triangles.
3. Explain the properties of similarities of triangles.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Analysis of Shapes
2. Current elementary textbook series
3. Paper, scissors, ruler, protractor, metric ruler, graph paper, tracing paper, compass.

PROCEDURE:

1. In MMP, Analysis of Shapes, do
   Activities 11: Items 1, 2, 4, 5, 6, and 7c
   12: Items 1, 2, 3, and 4
   13: Items 1, 2, 3, 4, 5, and 7
2. Prepare a game or an activity to be used in connection with teaching a concept learned in this MOD.

FINAL ASSESSMENT:

1. Bring all work sheets and your game to the evaluation.
2. Be prepared to take a written test on concepts in this MOD.

MOD 258 The Laws of the Universe

PREREQUISITE: MOD 153 Newton's Laws

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Demonstrate graphically Kepler's first and second laws.
2. Solve simple algebraic problems using some of the laws covered.
3. Demonstrate physically Newton's second law.
4. Explain any of the other laws discussed in the MOD.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Modern Physics by Dull, Metcalf, and Williams
2. Principles of Physics by Bueche
3. Exploration of the Universe by G. Abell
4. Astronomy One by Hynek and Apfel
5. Astronomy by Bash
6. The Science of Astronomy
7. Our Planet in Space by Navarra and Strahler (second part)
8. Two thumb tacks, length of string at least two feet long, graph paper, sheet of plywood (about 10 in. x 12 in.)

EXPLANATION:

You have already noted, by readings and by some direct demonstrations, how forces acting against objects can and usually do cause motion, or, at least, a change of state to occur in the objects acted upon. This idea will be further explored in this MOD, along with some ideas regarding light (and other electro-magnetic radiation) and electric and magnetic fields. Newton's Laws of general motion will be further examined, as we move into the area of gravitational forces; Kepler's Laws will be considered, as we look at some of the results of the sun exerting gravitational forces on the planets. The inverse square law of illumination will tell us how light (and other types of radiation) decrease with the square of the distance from the source. In a similar manner, Coulomb's Law will tell us how the force of attraction or repulsion, i.e. the electric field around a charged particle decreases with the square of the distance from the particle. Boyle's Law will explain how gases behave with respect to pressure and volume.

PROCEDURES:

1. Read in Modern Physics by Dull, Metcalf, and Williams pp. 81-89 on Newton's Laws of Motion. Be able to cite two examples of everyday phenomena that demonstrate each of these three laws. Read and concentrate on questions 1, 2, and 3 on p. 89. Work problems 1, 2, and 3 on p. 90.
2. Read in Astronomy by Bash pp. 115-116 on ellipses. With a string and two tacks, make three or four ellipses of different sizes and eccentricities. Now, as you read Kepler's three laws of planetary motion (in The Science of Astronomy, pp. 80-81; G. Abell's The

Exploration of the Universe, pp. 36-41; Hynek and Apfel's Astronomy One, pp. 223-224; and Navarra and Strahler's Our Planet in Space, second part, pp. 89-94) you will note that they completely govern the movements of not only the planets, but all celestial objects that might be (or come) within the gravitational field of another object.

3. Read Chapter 8 in the The Physical Sciences by Winter. Then, in Modern Physics by Dull, Metcalf, and Williams read the topic "Universal Gravitation" on pp. 91-92. Especially pay attention to the statement and equation of the Universal Law of Gravitation. Note that G is a constant of gravitation in the equation. We usually use the MKS system for problems of this nature, and here G is equal to $6.67 \times 10^{-11} \mathrm{nm}^2/\mathrm{kg}^2$. Go back once again and define the newton, the meter, and the kilogram, if you need to.
   Also read in Principles of Physics by Bueche, topic 5.1, Newton's Law of Gravitation on pp. 73-75.
4. Read in Principles of Physics by Bueche, the Inverse Square Law of Radiation, pp. 475-476. Read Hynek and Apfel's Astronomy One, pp. 40-42 on the Inverse Square Law, and read pp. 131-132 in The Exploration of the Universe by G. Abell.
5. Read in Modern Physics by Dull et al, "The Force between Charges," on pp. 389-390, and the sample problem on p. 391. Also read in Principles of Physics by Bueche, Coulomb's Law on p. 294 and the sample problems on p. 295.
6. Read in Modern Physics by Dull, Metcalf, and Williams pp. 200-207, especially concentrating on Boyle's Law.

SAMPLE PROBLEMS RELATING TO SOME OF THE LAWS YOU HAVE STUDIED
WORK THEM.

1. Relating to Kepler's third law (the harmonic law) determine the sidereal period of a planet that is located 6.5 a.u. from the su..

2. Relating to Newton's second law, what force is required to accelerate an object having a mass of 3 kg at 5m/sec^2? What is the mass of an object which is accelerated 10 ft/sec^2 by a force of 25 lb.?

3. Relating to the Universal Law of Gravitation find the force of attraction between two objects if one has a mass of 125 kg and the other a mass of 75 kg and they are located 3 m apart.

What is the force of attraction between a man of 90 kg and a woman of 60 kg if they are ½ m apart? . . . There must be something other than gravity.

4. Relating to the inverse square law of illumination, if object A is 6 feet from a light source, and object B is 12 feet from the same source, how much more light does object A get, per unit area, than object B?

5. Jupiter is about 5 times as far from the sun as earth is. How much more light does earth get, per unit area, than Jupiter?

MODs 259-261 Teaching Science

These MODs are designed to allow you the opportunity to identify, with the classroom teacher, needs of the children of a classroom at the grade level of your choice and to plan and teach a small unit or series of activities to meet those needs.

OBJECTIVES:

At the conclusion of these MODs you should be able to, when given an area in science, plan, teach, and evaluate a unit to a group of elementary children with greater confidence and competence.

INSTRUCTIONAL REFERENCES AND MATERIALS:

References and resources in the SME Resource Center

PROCEDURES:

1. During the first two weeks of the semester report to Mrs. Yoo your grade level preference.
2. After arrangements have been made with an area teacher, meet with the teacher to identify your teaching area and to establish a schedule. Your teaching should involve at least three periods.
3. Prepare a plan for your teaching, including at least the following components, and review it with an ISMEP staff member.
    - Title
    - Grade level
    - Objectives (written in behavioral terms)
    - Materials
    - Procedures
    - Evaluation Plan
4. Make three copies of the plan--one for the teacher, one for the ISMEP file, and one for yourself.
5. Complete the teaching, and sign up for a review of the experience with the ISMEP staff person who reviewed your plan.

FINAL ASSESSMENT:

Successful completion of the MODs will be determined from input from the classroom teacher and the post-teaching review. The post-review may include the classroom teacher or may include written input from her.

MOD 262 Planaria and Regeneration
Formulating hypotheses, experimenting

PREREQUISITE:

After completing objective 1, you will present your experimental plan to the instructor for approval before you begin the experimental work.

OBJECTIVES:

1. You will be able to plan an experimental design which will allow you to test the validity of a hypothesis you have stated in the experimental design.
2. In doing your experiment, you will be able to name the variables held constant, the manipulated variable(s) and the responding variable( ) in the experiment.
3. You will be able to discuss with the instructor your experimental results, drawings, recorded observations, and data, and you will be able to use them to support or refute the hypothesis you formulated for objective 1.
4. After doing your experiment, you will be able to make some positive statements about how the experimental design you formulated for objective 1 might be improved.
5. After doing your experiment, you will be able to state one new hypothesis that you might formulate as a result of your work.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. Wodsedalek, General Biology Laboratory Guide, pp. 144-146
2. Elliot, Laboratory Guide for Zoology, pp. 59-63
3. Keeton, Laboratory Guide for Biological Science, pp. 300-302
4. Weisz, The Science of Zoology, pp. 571-573
5. This MOD
6. General biology texts in Resource Center
7. Living planaria, dishes, and other material that will depend on the design of the experiment

FINAL ASSESSMENT:

See objectives above. Bring experimental data and animals to the evaluation.

PROCEDURE:

General Information:

MOD 262 has two main thrusts. One of these determines that you gain experience in planning an experimental design. The other directs you to do the experiment in order to determine the effectiveness of the experimental design in verifying or nullifying your hypothesis. There are many styles or patterns that one can use in formulating an experimental design leading to research [illegible] that are valid examples of scientific method. However, one does need to follow certain steps or thought processes from which is usually formulated a written plan or outline. Most scientists will agree that all knowledge about the natural world begins with directly or indirectly observing things in nature. Our observations result in the accumulation of simple, possibly isolated, facts. If you watched the sun come up this morning, you gained a piece of factual information. If you noticed that it came up at 6:30 a.m., you gained a second fact. If you noticed that the sun apparently moves from east to west, you gained more factual information. It is only through an accumulation of facts about a certain phenomenon that one can ask an intelligible question about the phenomenon. The formulation of a question then is a second important step leading to an experimental design.

From the discussion above, one may get the impression that every scientist in formulating an experimental design needs to begin with self-observed simple phenomena. However, it is equally possible to formulate a good question regarding the generalization, hypothesis, or theory of someone else. For example, if in your reading about planaria regeneration, you observe the statement made by someone else that "all planaria have an ability to regenerate lost body parts," you might formulate a question about this scientific generalization. Of course it would be assumed that you have accumulated enough factual material, through reading or observing, about planaria regeneration to question a major theory or concept.

A third step leading to an experimental design requires the posing of an answer, a guess, or a solution to the problem you have stated in step two above. Your "good guess" or answer to the question is usually called your hypothesis.

Once you have stated or formulated your hypothesis, you must test it. Such testing requires that you do further observing and/or experimenting. Experimentation is the most difficult part of research in that its fruits hinge on several important factors. It is necessary that the experimentation be designed so that it will test the hypothesis. It is necessary that the results be accurately observed and interpreted without bias or prejudice. Remember, it is easier to see something if you know what you are looking for. Very often an answer is over-looked because the researcher has his eyes strained for a different answer or result. It may even be possible to see something that is not there if the researcher is convinced that it should be there. Experimentation most often requires a design that allows the researcher to clearly distinguish between the controlled variables, the manipulated variable(s) and the responding variable(s). Another important aspect of experimentation is that it is designed and recorded so that it can be repeated exactly by other researchers. Any one experimental effort to to test a hypothesis is only a beginning. Every hypothesis must be tested many times, by various researchers, before it can be given any degree of validity. Once it has a high degree of validity or certitude it can be called a theory.

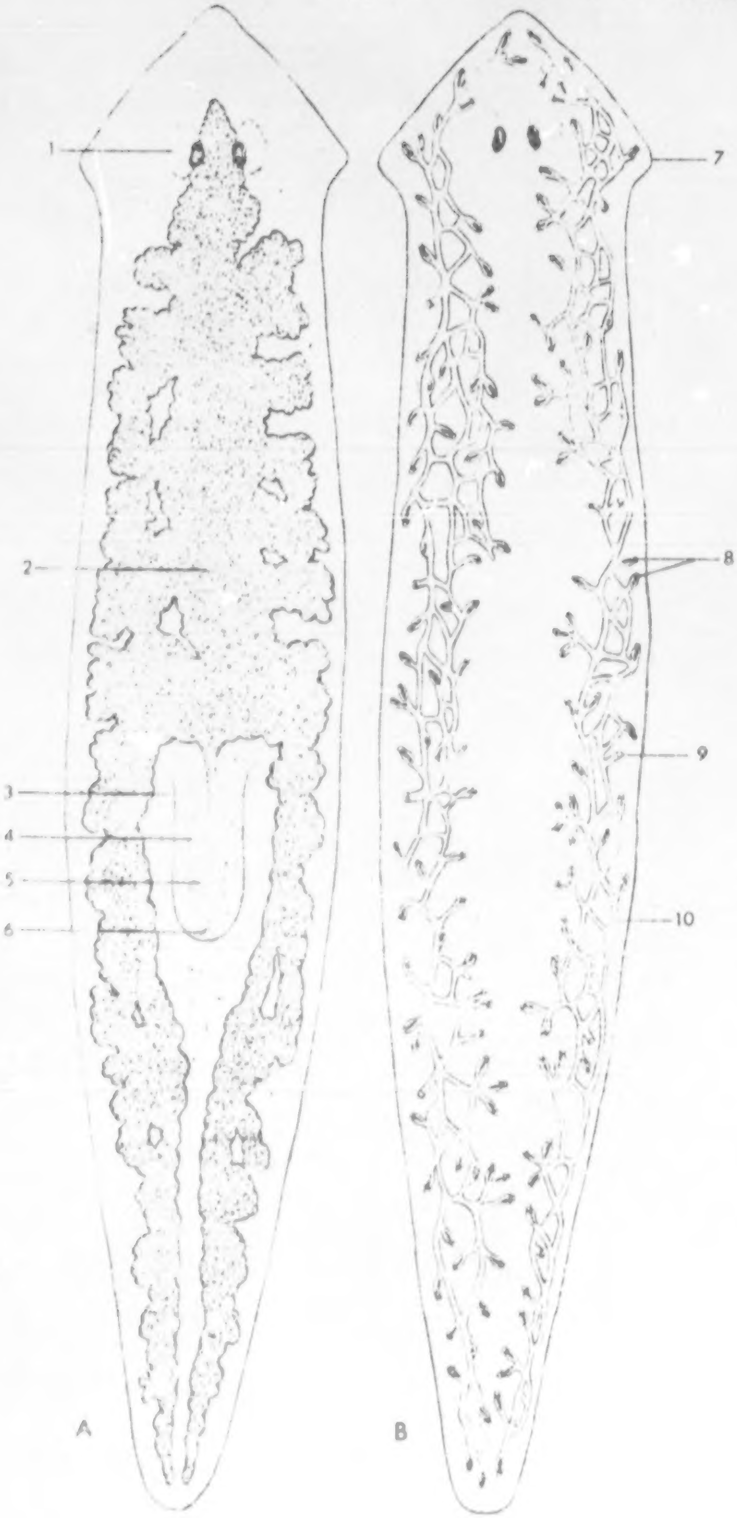
The analysis of the results of any experiment must always lead to new insights that are directly related to the hypothesis being tested. These new insights lead to a final step in the scientific method. This final step requires or initiates additional experimentation. Additional experimentation which requires the formulation of new hypotheses, new experimental designs, and hence perpetuates the quest for scientific truth.

Activity:

If you have read the above information you will realize that your first goal in doing this MOD is to review some of the literature dealing with the scientific method and with planaria regeneration. It is granted that the literature cited is not exhaustive in terms of information about planaria regeneration. However, it should provide you with facts which will allow you to ask a question about some facet of regeneration in planaria. For example, you might ask: Will planaria regenerate in the dark? Will planaria regenerate if only one piece is in a dish? Do all the sections participate in the regeneration of any one section? Will planaria regenerate if they are constantly stirred? Once you have asked a question, you can formulate a hypothesis and plan an experimental design which will test your hypothesis.

Be sure to read the objectives and understand them before you proceed with this MOD.

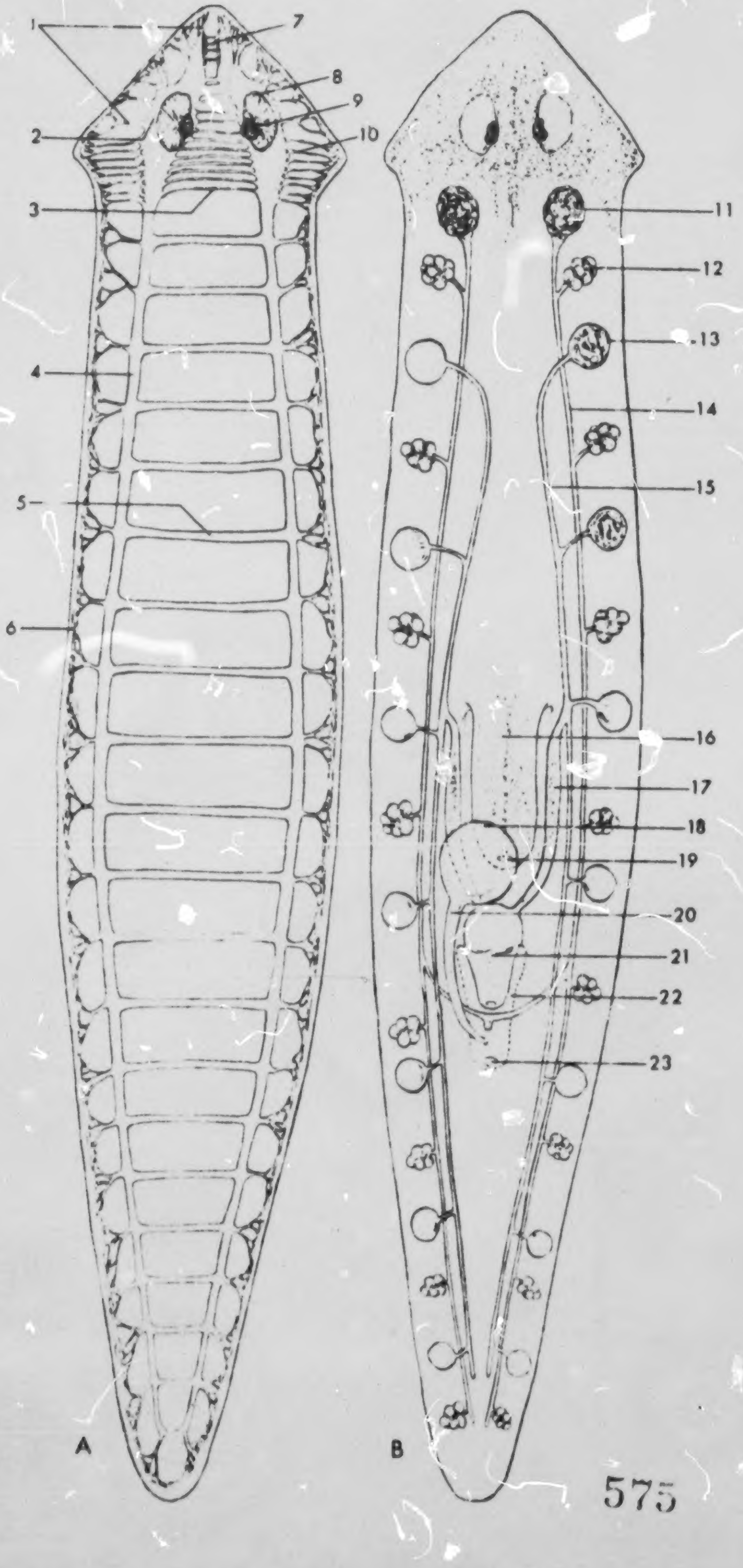
PLANARIAN ANATOMY 2.
Digestive and Excretory Systems



A. Digestive system, triclad
1. Eye
2. Intestine
3. Pharyngeal cavity
4. Pharynx
5. Mouth
6. Pharyngeal opening

B. Excretory system
7. Auricle
8. Flame cell
9. Excretory pore
10. Excretory tubule

PLANARIAN ANATOMY 3.
Nervous and Reproductive Systems



A. Nervous system
1. Main sensory brain nerves
2. Brain
3. Dorsal commissure between ventral cords
4. Ventral nerve cord
5. Transverse commissure
6. Marginal plexus
7. Anterior continuation of ventral cords
8. Eye, nerve cells
9. Eye, pigment
10. Ventral sensory nerve

B. Reproductive system
11. Ovary
12. Yolk gland
13. Testis
14. Oviduct
15. Sperm duct
16. Pharynx
17. Spermiducal vesicle
18. Copulatory sac
19. Pharyngeal opening
20. Bursal canal
21. Penis papilla
22. Genital chamber
23. Genital pore

MOD 263 Analysis of Circles

This MOD is designed to provide some interesting properties of circles for analysis.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Observe the occurrences, both physical and conceptual, of circles in your life.
2. Analyze circles and their relationships with points, lines, Cartesian coordinates, etc.
3. Make applications of what you have learned about circles.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Analysis of Shapes
2. Elementary textbook series
3. Compass, straightedge, protractor, graph paper

OBTAIN ALL THESE MATERIALS IN RESOURCE CENTER EXCEPT FOR THE GRAPH PAPER.

PROCEDURE:

1. In MMP, Analysis of Shapes, do:
   Activities 16: Items 1, 2 (write why), 3, 4, and 5
   17: Items 1, 2, 3, 4, and 5
   18: Items 1, 3, 4, and 5
   19: Items 1, 2, 3, 5, 6, and 7
   21: Items 1 and 2
2. Create a game or activity to be used in teaching a concept learned in this MOD.

FINAL ASSESSMENT:

1. Bring all work sheets and your game to the evaluation.
2. Be prepared to take a written test as a part of the evaluation.

MOD 264 Heating and Cooling
Inferring

OBJECTIVES:

1. Given the materials found in the MOD tray, you will carry out empirical investigations regarding heating and cooling. Your investigations will correspond to at least 12 out of the 22 Problem Cards shown in Heating and Cooling, pp. 14-43. You will keep a written record of your investigations.
2. You will formulate at least two good questions regarding the phenomena encountered in your investigations. With the help of references on the physics of heat, you will formulate an answer for at least one of your questions.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS. Heating and Cooling, Teacher's Guide
2. Physical science texts
3. Candles, clothespins, water pails
4. Solid and hollow metal rods of different diameters, sheet metal, pieces of screening, wire made of various metals

FINAL ASSESSMENT:

1. Submit the written record corresponding to objective 1 and be ready to discuss it with your instructor.
2. See objective 2.

MOD 265 **Gerbils and Mazes**
Experimenting, interpreting data

OBJECTIVES:

1. **After constructing a maze, you will determine the ability of gerbils to learn a pathway to a food source.**
2. **After performing seven test runs with a gerbil, you will communicate your data by putting it into graph form.**
3. **After setting up your experimental design according to page 2 of this MOD, you will name at least two controlled variables, two manipulated variables, and two responding variables.**
4. **After conducting the experiment, you will list three or four things that you feel you should have included, done differently, or excluded in the experiment.**

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, The Curious Gerbils
2. SAPA 63, Maze Behavior
3. SAPA 66, Learning and Forgetting
4. SAPA 38, Using Graphs
5. SAPA 36, Animal Responses
6. Gerbil, Boards, rubber bands, sunflower seeds, gerbil cage, maze tracing paper

FINAL ASSESSMENT:

See objectives above. Bring to the evaluation a tracing of the maze and a graph which communicates the collected data.

PROCEDURE:

1. Read The Curious Gerbils, an ESS information booklet by Morrison and Morrison.

2. Obtain a gerbil from the Prep Room and place it in a cage on a metal tray. Place the cage on the floor of room MN 214 for a period of two days. Supply it with the food and water provided in the room.

3. Obtain a piece of brown wrapping paper that is 4-6 feet long and construct a maze on it. Trace the outline of the maze on the paper. The maze should be constructed so that, when opened, the cage door will permit the gerbil to enter the maze. Once you have constructed the maze, the cage and the maze should be left in the same position during the entire experiment.

4. Remove all food and water from the cage on the evening of the second day.

5. Sometime during the third day, place food in one of the maze areas and open the door of the cage.

6. Record the pathway that the gerbil takes and the time it takes for the gerbil to reach the food.

7. As soon as the gerbil reaches the food, return it to the cage and supply food and water for the rest of the day. Remove the food and water in late afternoon or evening.

8. Repeat steps 4 through 7 for six more trials.

9. After completing the exercise, return the gerbil to the Prep Room, clean the cage and the area, and dismantle the maze. Keep the paper tracing of the maze, and bring it to the oral evaluation.

10. Communicate your data by making a graph, and then interpret the graph.

11. From your data, formulate at least five concluding statements about the experiment and the results.

MOD 266 Acids, Bases, Indicators (Group Activity)
Observing, inferring

OBJECTIVES:

1. Given some red cabbage leaves and utensils in which to boil them, you will prepare red cabbage juice and red cabbage indicator paper.
2. Given 3 liquid indicators (phenolphthalein, methyl orange dye, and red cabbage juice), you will demonstrate their behavior in 6F NaOH, 6F HCl, and distilled water.
3. Given 2 paper indicators (litmus and red cabbage), you will test at least 12 household items for their acid and basic properties.
4. You will describe at least one indicator change in common household activity, for example, cooking, laundering, cleaning.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. This MOD, pp. 2-4
2. Sections of basic college chemistry texts on acids, bases, and indicators
3. College chemistry majors
4. Phenolphthalein, methyl orange dye, red cabbage juice, litmus paper, red cabbage paper, various household items
5. Cooper, Elizabeth K., Discovering Chemistry, New York: Harcourt, Brace, and World, 1959, pp. 112-114

FINAL ASSESSMENT:

1. See objectives above.
2. Check your lab sheets with the instructor.

PROCEDURE:

Useful information about indicators

Acid - a substance that contributes hydrogen ions (H^+) to a solution.
Base - a substance that contributes hydroxyl ions (OH^-) to a solution.
Indicator - a substance that changes color in acids and bases. The color change is due to chemical change.

Various kinds of indicators:
a. Phenolphthalein and methyl orange - complex organic dyes
b. Litmus - a complex vegetable structure extracted from lichens
c. Flower, fruit, and vegetable indicators

Flower Indicators
Directions for making your own chemical indicators from natural materials are given by Elizabeth Cooper in Discovering Chemistry, pp. 112-114. The following adaptations have been made from this useful book for elementary school teachers. Cut the blossoms of the flowers or fruit into tiny pieces. Put them in a glass jar. Put a silver spoon or knife into the jar to absorb some of the heat. Pour about one-half cupful of boiling water over the flower bits. Let each jar stand until the color is extracted from the flower and the solution becomes colored. Soak some soft white paper in the liquid and let the paper dry. Use this same procedure to make each indicator. The following activities will be useful in your teaching.

a. Violets
Several dozen violets will turn the solution a deep greenish-blue. This will turn red with acids and green with bases.

b. Hollyhocks
Purple hollyhock blossoms will produce paper especially sensitive to acids and bases. This paper called "Mallow Paper" is made and used commercially.

c. Purple Dahlias and Purple Iris
Pieces of purple dahlias make a purplish solution.

Fruit Indicators
Cherries, huckleberries, and elderberries can be used to make test papers. Crush the deep red and purple fruit to extract as much of the purplish juice as possible. Soak soft white paper in the colored juice, letting the paper absorb as much juice as it can hold. Dry the paper in a shady place. When dry, mark the paper with the name of the fruit. Test its alkali or base reaction with a few drops of household ammonia. Notice how the papers vary in sensitivity.

1. Red Cabbage Liquid and Paper Indicator
In this MOD, you will work only with red cabbage indicator. Liquids also change color in the presence of acids and bases. To make a liquid indicator chop into tiny pieces some dark purple red cabbage leaves or red beets. Put

a cupful of the chopped pieces into an enamel pan or pyrex container. Do not use aluminum. Add enough water to cover the pieces. Put the pan on the stove and boil the vegetable gently for at least twenty minutes. When it is cool enough to handle, pour the colored liquid into glass bottles or jars. To test the indicator fill a test tube about one-fourth full of the liquid. Add a measure of baking soda. Observe the color change in the solution from purplish red to green. The baking soda has made the solution basic.

Then add a few drops of vinegar at a time. Gradually, the green color disappears as the vinegar neutralizes the solution. Continue to add vinegar until the red color indicates your solution has become acid.

Then make cabbage indicator paper by cutting small strips of newspaper or white paper toweling and soak them in the liquid. Soak the strips until they turn purple and dry them in a shady place. This paper will turn pink when it is dipped into an acid and it will turn green in a base. It should be handled with clean hands and kept in a covered container when it is not in use.

2. Test the behavior of the following indicators by putting two or three drops of each in about 5 ml. of each of the given reagents:

	.25M HCl	.25M NaOH	Distilled Water
Phenolphthalein			
Methyl Orange			
Red Cabbage Juice			

3. Place a little of the indicator in about 5 ml. acid. Then add hydroxide until the solution is basic. Then add acid until the solution is again acidic. Describe what happens.

Phenaophthalein

Methyl Orange

Red Cabbage Juice

4. Many common household materials are acids or bases. Test small portions of each of the following with litmus paper and with red cabbage paper and record the results. If the material is a solid, dissolve a little of it in distilled water. Prepare two test tubes each of 6F HCl, 6F NaOH, and distilled water to separately test each paper. Put the paper in the test tube and use its color as a standard for comparison in the tests below. Determine in each case whether the substance is acidic or basic.

Household Item	Litmus Paper	Red Cabbage Paper	Acid or Base?
Detergent			
Toilet Soap			
Vinegar			
Alka-Seltzer			
Saliva			
Fresh Milk			
Sour Milk			
Baking Soda			
Lemon Juice			
Table Salt			
Carbonated Beverage			
Household Ammonia			
Dry Bleach			
Bowl Cleaner			
Strong Cleaner (Ajax, Spic and Span)			

5. Describe at least one indicator change in common household activity, as cooking. laundering, cleaning.

MODs 267-269 Teaching Mathematics

These MODs are desgined to allow you the opportunity to identify, with the classroom teacher, needs of the children of a classroom at the grade level of your choice and to plan and teach a small unit or series of activities to meet those needs.

OBJECTIVES:

At the conclusion of these MODs you should be able to, when given an area in mathematics, plan, teach, and evaluate a unit to a group of elementary children with greater confidence and competence.

INSTRUCTIONAL REFERENCES AND MATERIALS:

References and resources in the SME Resource Center

PROCEDURES:

1. During the first two weeks of the semester report to Mrs. Yoo your grade level preference.
2. After arrangements have been made with an area teacher, meet with the teacher to identify your teaching area and to establish a schedule. Your teaching should involve at least three periods.
3. Prepare a plan for your teaching, including at least the following components, and review it with an ISMEP staff member.
    - Title
    - Grade level
    - Objectives (written in behavioral terms)
    - Materials
    - Procedures
    - Evaluation Plan
4. Make three copies of the plan--one for the teacher, one for the ISMEP file, and one for yourself.
5. Complete the teaching, and sign up for a review of the experience with the ISMEP staff person who reviewed your plan.

FINAL ASSESSMENT:

Successful completion of these MODs will be determined from input from the classroom teacher and the post-teaching review. The post-review may include the classroom teacher or may include written input from her.

MOD 270 Judging Elementary Science Projects

This MOD is designed to provide you an opportunity to view science projects prepared by elementary children and to allow you to apply objective criteria in judging the scientific value of the projects.

OBJECTIVES:

After participating in this MOD, when given a science project and a set of criteria you should be able to evaluate the project and assign a rating with increased reliability and confidence.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Woodburn, John H. and Osbourn, Ellsworth S., Teaching the Pursuit of Science, pp. 448-459
2. References in Resource Center and University Curriculum Library
3. Sample attached forms

PROCEDURE:

1. Prepare a short report (1-2 pages) on science projects and/or science fairs incorporating some advantages and disadvantages. You may utilize references and your own experience.
2. Review the forms used for the 1978 North Calloway Elementary Science Fair (included in this MOD).
3. Assist with judging a science fair at an area elementary school. Time and place will be announced.

FINAL ASSESSMENT:

Completion of the MOD will be accomplished by submitting, in good form, your report and by your participating in the judging of an elementary science fair.

CRITERIA for JUDGING EXHIBITS

1. Creative ability. . . . . . . .30 points
How much of the work appears to show originality of approach or handling? Judge that which appears to you to be original regardless of the expense of purchased or borrowed equipment. Give weight to ingenious use of materials, if present. Consider collections creative if they seem to have a purpose.

2. Scientific thought. . . . . . .30 points
Does this exhibit disclose organized procedures? Is there a planned system, classification, accurate observation, controlled experiment? Does this exhibit show a verification of laws, a cause and effect, or present by models or other methods a better understanding of scientific facts of theories? Give weight to probable amount of real study and effort which is represented in the exhibit. Guard against discounting for what might have been added, included, or improved.

3. Thoroughness . . . . .10 points
Score here for how completely the story is told. It is not essential that step-by-step elucidation of construction details be given in working models.

4. Skill. . . . . .10 points
Is the workmanship good? Under normal working conditions, is the exhibit likely to demand frequant repairs? In collections, how skilled is the handling, preparation, mounting, or other treatment?

5. Clarity. . . . . .10 points
In your opinion, will the average person understand what is being displayed? Are guide marks, labels, descriptions neatly yet briefly presented? Is there sensible progression of the attention of the spectator across and through the exhibit?

6. Dramatic value . . . . .10 points
Is this exhibit more attractive than others in the same field? Don't be influenced by "cute" things, lights, buttons, switches, cranks, or other gadgets which contribute little to the exhibit.

The Science Clubs of AMERICA have set up the above criteria to be used at regional and national science fairs throughout the United States.

SCIENCE FAIR EVALUATION SHEET

Exhibitors Number ____________________

Exhibitors Name ____________________

Criteria	Possible Points	Actual points
1. Creative ability	30	
2. Scientific thought	30	
3. Thoroughness	10	
4. Skill	10	
5. Clarity	10	
6. Dramatic value	10	
TOTAL POINTS		

SCIENCE PROJECT EVALUATION

Students Name ______________________

____

Name of Project ______________________

	POINTS	JUDGES	GRADE	COMMENTS
Project turned in on time	60			
Time spent on Project	20			
Orginality	10			
Science Concept 1) Is it easily recognized	10			

COMMENTS

70-76 = D

77-87 = C

88-94 = B

95-100= A

Rules for North Calloway Science Fair in Sixth, Seventh and Eighth Grade

1. North Calloway Science Fair will be held April 5, 6, and 7 in the gym.
2. Prices will be awarded in each grade. Overall first, second, and third place prizes will be awarded also. All participants will be awarded ribbons.

First prize	$5.00
Second prize	3.00
Third prize	2.00

3. Each person in the sixth and seventh and eighth gardes must have a project. It will count 1/3 of the six weeks science grade.
4. No more than two persons may work together on one project and they have to be in the same class section.
5. All projects will be explained in class.
6. Projects may be entered in science, math, or health.
7. Late projects will not be accepted unless students are absent the day of the science fair and are excused by the principal.
8. Projects must be done at the expense of the student and work must be done by the student outside of class. Money spent will be up to the parent and student.
9. All prize winners must enter their projects in the MSU Science Fair in April 1978 at the Livestock Pavilion or not accept the prize.
10. Extra points toward science grade will be given to all who visit and view the MSU Science Fair. Check off your name with the list Mr. Walker or Mrs. Beach has on that day.
11. April 6 at 7:00 all parents are invited to view the Science Fair at North after the regular PTC meeting. You are encouraged to attend.

****

ENTRY BLANK FOR NORTH SCIENCT FAIR

NAME OF PERSON OR PERSONS: ______________________________

TITLE OF PROJECT: ______________________________

BRIEF DESCRIPTION OF PROJECT: ______________________________

____

We have read and understand all of the above science fair rules.

Due fact to teacher March 17.

____
Parents signature

____
Student signature

MOD 271 Multiplication and Division in the Elementary School

OBJECTIVES:

At the conclusion of this MOD you will:

1. Have insight into the order in which children learn multiplication and division.
2. Gain insight into the age of children for each developmental stage of multiplication and division.
3. Be able to introduce conceptual development with a degree of confidence.
4. Be able to help a child bridge the gap between a problem and the mathematical symbols used to represent the problem.
5. Be able to encourage children to learn or memorize basic multiplication and division facts.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Multiplication and Division
2. MMP Slide/tape, "Multiplication and Division in the Elementary School"
3. Current elementary mathematics text series
4. Chips

PROCEDURE:

1. View the slide/tape, "Multiplication and Division in the Elementary School."
2. In MMP, Multiplication and Division, do:

Activities 3: Items 1 and 2
4: Items 1, 2, 3, and 4
5: Items 1, 2, 3, 4, 5, and 6 (Play the chip game.)
7: Item 2
8: Part 1; Items 1 and 2
Part 2; Items 1, 2, 3, 4, 5, and 6
10: Items 1, 2, 3, and 4
11: Items 1 and 2(Laminate)

3. Find at least two games to aid a child in learning multiplication and division.

FINAL ASSESSMENT:

1. Bring all work papers and games to the evaluation.
2. See objectives.

MOD 272 Multiplication and Division Algorithms

This MOD is concerned with development of the algorithms for multiplication and division.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Help children progress from real-world problems to symbols without using concrete models.
2. Help children develop an understanding of the algorithms.
3. See the algorithms as efficient procedures for calculations in multiplication and division.
4. Recognize some patterns for algorithms.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Multiplication and Division
2. Dienes blocks, bundling sticks, Cuisenaire rods, graph paper, crayons
3. Current elementary mathematics textbooks

PROCEDURE:

1. In MMP, Multiplication and Division, do:
   Activities 13: Items 1, 2, 3, 4, 5, 6, and 9
   14: Items 1(See Instructor's Manual after you have matched the activities with the objectives) and 2
   16: Items 1, 2, 3, and 4
   17: Items 1, 2, 3, and 5
   19: Items 1, 2, and 3
   20: Items 1 and 2
2. Prepare a game to reinforce a concept you have learned involving algorithms.

FINAL ASSESSMENT:

1. Bring all work papers and your game to the evaluation.
2. Be prepared to answer questions relative to objectives.

MOD 273 Multiplication and Division

This MOD is designed to increase your confidence in teaching the division algorithm.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Design a sequence of steps to help children learn to divide with larger numbers.
2. Understand the division algorithm completely.
3. Illustrate the importance of estimation in division.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Multiplication and Division
2. Current elementary mathematics textbook series

PROCEDURE:

1. In MMP, Multiplication and Division, do
   Activities 21: Items 1 and 2
   23: Items 1, 2, 3, and 4
2. In MMP, Multiplication and Division, read and discuss with your partner the steps presented in Activity 22.

FINAL ASSESSMENT:

Bring all work sheets to the evaluation.

MOD 274 Inquiry Teaching Strategies

This MOD is designed to provide variety to the program and to offer the expertise of a nationally recognized mathematician, scientist, or educator. This MOD is scheduled as a group activity on a date to be announced.

OBJECTIVES:

The objectives will be determined by the seminar director.

INSTRUCTIONAL REFERENCES AND MATERIALS:

None

PROCEDURE:

Attend and participate in the scheduled seminar and the open lecture.

FINAL ASSESSMENT:

This MOD will be satisfactorily completed by attending and participating in the scheduled seminar and the open lecture.

MOD 275 Interpreting Aerial Photographs

OBJECTIVES:

1. Given aerial photographs of the Murray area you will be able to:
    a. identify the four directions, N, S, E, W, using a recognizable reference point of your choice in the photographed landscape;
    b. arrange the four photos of Murray to form a composite;
    c. trace the city boundaries of Murray;
    d. make inferences regarding geographical and meteorological conditions.
2. Using the topographic maps for reference, you will be able to:
    a. prepare a verbal scale for the given photographs;
    b. infer causes of physical land changes or discrepancies between the maps and photographs.
3. Given a topographic map, you will be able to perform the following tasks:
    a. interpret contour intervals by pointing out relatively high and low areas of the map;
    b. interpret depression and elevation contours;
    c. distinguish between cultural (man-made) and natural features and identify various features;
    d. express the scale of the map by using verbal, fractional, or graphic means.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Seven 1:24,000 topographic maps including Murray and Calloway County, Kentucky
2. One 1:250,000 topographic map including Murray and Calloway County, Kentucky
3. Four small and four enlarged aerial photos including Murray, Kentucky
4. TVA, Maps Are for Fun! Knowledge!
5. Boy Scout Manual, Orienteering, found in the MOD tray

FINAL ASSESSMENT:

1. See objectives.
2. Bring to the assessment all answer sheets, the maps, and photographs and be prepared to demonstrate your proficiency at interpreting aerial photographs and topographic maps by answering questions similar to ones in the activities.

PROCEDURE:

Information on Aerial Survey and Photography

The photographic record registers minute, frequently elusive and transient, details that could never have been entered on the most painstaking map. The comprehensive photograph is at once up to date. It gives the whole truth, whereas a map is always a highly selective reduction of nature to conventions and symbols.

From its inception, aerial photography has employed two basic types of view: vertical and oblique. Oblique views are usually taken from a relatively low altitude, with either a hand-held or fixed camera slanted obliquely at the ground. They give a perspective view with a better impression of landforms than vertical views.

Vertical photographs demand more exacting apparatus, since the optical axis should be precisely perpendicular to the earth's surface. Special cameras are designed and mounted on the underbelly or cockpit of the plane. Vertical shots possess only the more salient properties of map projections. The scale depends upon aircraft altitude and lens focal length. Features can be transferred from a vertical photograph to a conventional map, thereby helping to locate the field. The success of such an operation hinges on the establishment of recognizable control points in the photographed landscape.

Some possible sources of error include aircraft drift due to side winds and tilt, which may be eliminated by rotating and gyrostabilized camera mounts, while height variations can be corrected by re-scaling in the enlarger. For added accuracy, many cameras record such data as the aircraft's height, altitude, heading and position and the time at the moment of exposure on the film rebate. Difference in scale between the edges and center of the picture is unavoidable, but can be reduced by using long-focus lenses. However, economics or low clouds may prevent this. Haze, ever-present at any altitude, can usually be overcome by use of appropriate filters and emulsions.

In general, aerial survey falls into two categories, qualitative or quantitative and photogrammetric. The first is mainly concerned with size, shape, tone and texture. Some overall distortion is acceptable in many cases. Its applications lie in agriculture, archeology, and military reconnaissance.

In photogrammetric survey, position and direction and undistorted reproduction are most important. Photogrammetry is the science of making measurements from photographs. This is done through stereoscopic analysis. Along with accurate positional and directional data, an overlapping of photos is necessary to prepare them for stereoscopic viewing. There is a 60% minimum overlapping; this facilitates the identification of objects. Measurements can be taken by hand, but are usually done by electronic scanning or on complex plotting machines. These employ twin projectors over a large plotting table, coupled to a small movable table or floating mark. Results can be converted directly to contours or stored for subsequent processing in a computer. Either way, the end product is usually a contoured map or series of elevations, even perhaps a three-dimensional terrain model, complete with minature buildings and trees.

The most common application of aerial survey is in the geographical and geological fields. Besides eliminating a vast amount of tedious field work, it is sometimes the only way of mapping and analyzing large and inaccessible areas. However, it has not yet completely supplanted ground surveys, where they are possible. Apart from this, repetitive surveys of inhabited regions are valuable in showing the growth of land development, communications and coast erosion, particularly where buildings hamper ground work.

In the same way, aerial survey is of use in agriculture and forestry, to show the growth of crops and the condition of land. In ecology and botany it has proved its value in showing the distribution of animal and vegetable life and in the treatment of pests. Because the surface of the ground, once disturbed, is never the same again, the aerial camera can be used in archaeology. Here it can show the tonal differences in soil or vegetation over buried ruins that would be indistinguishable by ground observation.

References consulted:

Deuel, Leo, Flight Into Yesterday, New York: St. Martin's Press, 1969.

Kraszna-Krausz, A. (ed), The Focal Encyclopedia of Photography, "Aerial Survey" and "Photogrammetry," New York: McGraw-Hill, 1969.

Activities:

Please do not mark the aerial photographs or topographic maps.

1. Spend a little time to familiarize yourself with the photographs. Then choose a recognizable reference point and use it to point out the four directions, N, S, E, W, on the photographs.

2. Cite several examples to prove that these photographs were taken after 1975.

a. ____

b. ____

c. ____

3. Find the north city boundary of Murray, using any data you wish. (No single photograph shows the entire area.)

4. Make copies of the four photos and arrange them to produce a photo of the city of Murray.

The topographic map may be consulted for questions 5 - 8.

5. **Using the topographic map, draw a verbal scale for the photographs. Let one inch be the basic unit.** 1 inch = ____________ **feet. Describe a means of testing the accuracy of your scale when it is applied to longer distances and to curved distances.**

6. Notice the various directions in which farmers appear to have plowed their fields (photograph KY552C044). State an inference explaining this.

____

____

7. State an inference explaining why the track appears to be white on the photograph KY552C042. Might there be multiple explanations?

____

____

9. State and locate the areas of highest and lowest relief on the photograph of your preference.

Highest ________________________. Lowest ________________________.

Read the information references before attempting to interpret the maps. Examine each topographic map and answer the questions pertaining to it.

Do not make any marks on topographic maps.

Murray Quadrangle, Murray, Kentucky

1. Obtain the following data:
   a. Last survey for this map ________
   b. Scale (fractional) ____________
   c. Contour interval ____________

2. Give the exact location of the highest point in the extreme Northwest corner of the Murray Quadrangle map. What is its height?

3. How would quadrangles in North Dakota and Florida, respectively, drawn on the same scale, compare in total area enclosed. Check the proper space below. Use a globe to help you.
   Quadrangles in North Dakota are larger_____smaller_____same_____as quadrangles in Florida.

4. What is the lowest contour shown in this section?_______.

5. Express the approximate verbal scale of this quadrangle.

   ____

6. Why do you suppose the tier numbers of the left margin are different from those on the right margin?

7. How many minutes of latitude______and longitude_______are included in this map?

8. Find Jonathan Creek on the Hico Quadrangle creek bed on this map.

   Jonathan Creek is a "meandering" creek. From this information can you tell if it is a relatively old or young river?___________. Explain.

9. "Downstream" is defined: "toward the direction of water flow." Find contour lines that cross streams and notice that the lines form a "V" where they cross the stream. Determine whether the "V" points upstream or downstream.___________ By looking at a river on the map, how do you know which way it is flowing?

10. Locate a closed contour with hachure marks.

    a. What do these marks signify?

    b. What has caused these features?____________________________________
    Speculate toward an answer before proceeding to the next item.

11. How many times larger is the Dyersburg map than the Murray Quadrangle map?______________. Show your work below.

MOD 276 Percent

The purpose of this MOD is to expand and reinforce your working knowledge of percents.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Change fractions and decimals to percents.
2. Change percents to fractions and decimals.
3. Solve word problems involving percents.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Elementary textbook series
2. Worksheets
3. A First Program in Mathematics by Heywood, pp. 343-410
4. First Course in Fundamentals of Mathematics by Stein, pp. 177-214
5. A First Course in College Mathematics by Willerding, pp. 194-237

PROCEDURE:

1. Review percents in one or more of the above references.
2. Do work sheets individually. Then check with your partner.

FINAL ASSESSMENT:

Prepare to take a written test.

Worksheets on Percentage

RULES

1. To change a decimal to a percent, move the decimal point two places to the right and put in a percent sign. For example, .56 = 56%

2. To change a percent to a decimal, drop the percent sign and move the decimal point two places to the left. For example, 64% = .64

I. Fill in blanks below.

Fraction	Decimal	Percent
3/4	.75	75%
9/10	____	____
____	____	65%
____	____	87½%
7/20	____	____
____	.08	____
____	____	251%
____	.063	____
1/100	____	____
____	6.7	____
____	____	10.2%
____	1.89	____
21/25	____	____

II. Change each of the following to a fraction or mixed number.

1. 320%
2. 7%
3. .7%
4. .07%
5. 36%
6. 270%
7. 1/3 %
8. 5%
9. 98%
10. .0405%

III. Change each of the following to a percent.

1. 4/25	6. $1\frac{6}{5}$
2. 2.589	7. 1/10
3. 1¼	8. 19/20
4. .345	9. $1\ \frac{50}{100}$
5. 3/4	10. 4/5

IV. Change each of the following to a decimal.

1. 2%	6. 1%
2. .75%	7. .5%
3. 481%	8. 2.37%
4. 6.3%	9. 82%
5. 153%	10. 26%

Statement: With percent problems, as with any word problems, no one rule will cover every problem. However, one useful approach is proportion. When solving percent problems, write the problem as a proportion in the following way:

$$\frac{\text{some number(known as the "part") compares to}}{\text{some other number (known as the "base")}} = \frac{\text{some percent compares to}}{100}$$

or $$\frac{\text{some quantity compares to}}{\text{some other quantity}} \quad \text{the way} \quad \frac{\text{some number}}{\text{compares to 100}}$$

For example: 1. On a certain test 8 students get a grade of A. This is 25% of this class. How many students are in the class?

Solution: $$\frac{8}{N} = \frac{25}{100}$$

$$800 = 25N$$

$$32 = N$$

2. A car salesman works for a 6% monthly commission. One month his sales are \$14,000. How much does he earn?

Solution: $$\frac{N}{14{,}000} = \frac{6}{100}$$

$$100N = 84{,}000$$

$$N = 840$$

Remember: If we know three terms in a proportion, we can find the fourth by cross multiplication.

Work the following practice problems.

1. Mr. Smith's commission is 7%. If he earned \$119 one week, what did his sales total?

2. A store is having a sale, and all books are being sold at a 25% discount. If Joan wants to buy a book that normally costs \$14, what is the discount?

3. There are 950 students in a certain school. If 57 are absent one day, what percent is absent?

4. A person borrows $150 at 11% interest per year. If nothing is paid back the first year, how much interest is owed at the end of the year?

5. Joan's doctor told her that her ideal weight is 130 pounds. If she weighs 143 pounds, what percent of her ideal weight is she now?

6. A dealer buys a jacker for $20. She has to sell it for $15. What is the percent loss?

7. A customer buys a refrigerator at a 15% discount. What does the customer pay if the marked price is $400?

8. In a certain test, 8 students get A's, 11 get B's, 9 get C's, and 4 fail. What percent get A's?

9. A box of 20 light bulbs costs $4.50. A laboratory finds 25% are defective. If the defective are worthless what is the price of each good bulb?

10. Deane bought a car for $2800 and sold it five years later for $700. What was the percent decrease in price?

MOD 277 Transformational Geometry (Seminar)

This MOD is designed to give a limited introduction to transformational geometry in the setting of a seminar.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Define transformational geometry.
2. Recognize and analyze rigid, projective, and topological transformations.
3. Describe (a) a slide transformation (b) a turn by locating its center and the direction of the rotation (c) a flip.
4. Use flips and turns to analyze the symmetries possessed by objects.
5. Use symmetry to analyze shapes.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Transformational Geometry
2. MMP Slide/tape, "Overview of Transformational Geometry"
3. Ruler, protractor, compass, construction paper, scissors, tracing paper, rectangular prism

PROCEDURE:

1. As a group the slide/tape "Overview of Transformational Geometry" will be viewed.
2. In MMP, Transformational Geometry, the Instructor will lead in discussions of Activities 1, 2, 3, 4, and 5.

FINAL ASSESSMENT:

At the conclusion of the seminar, you will have completed this MOD.

MOD 278 Equipment Construction for Elementary School Science

OBJECTIVE:

Given materials in the Resource Center or materials readily available from supermarket or hardward stores, you will construct a piece of equipment useable in elementary school science. You may find it possible to correlate this MOD with your teaching science MOD.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. The elementary science curriculum materials in the Resource Center
2. Schmidt and Rockcastle, Teaching Science with Everyday Things
3. UNESCO Source Book for Science Teaching
4. Resource books in the Resource Center and the University Curriculum Library
5. Other materials readily available from your surroundings, from supermarket or hardware stores

FINAL ASSESSMENT:

1. Present the equipment you build to your instructor, and operate it order to show that it is useable.
2. A display of the equipment will be set up during the first week of May.

PROCEDURE:

You may build two of the items listed below or items of your own choice. In the case of the latter, your choice must be approved by one of the instructors before you begin to build. Please sign the sheet provided on the bulletin board so that excessive duplication of equipment construction can be avoided.

Examples:

Balance
Whirly-bird (SCIS)
Stopper-popper (SCIS)
Pendulum support (ESS)
Barometer and thermometer
Gallon jar terrarium
Astrolabe
Periscope
Pinhole camera
Electric motor
Sextant
Assortment of musical instruments (ESS)
Ant farm (using a jar)
Tangram construction and set of cards to accompany set
Maze (mealworms, rats, gerbils)
Lever-pulley system (M.A. of 4 plus)
Skeleton, or parts of a skeleton
Wind vane, anemometer, and hygrometer
Galvanometer
Circuit board
Others. . .

See the following books, among others, for ideas:

Schmidt and Rockcastle, Teaching Science with Everyday Things
UNESCO Source Book for Science Teaching

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MOD 280 Environmental Study
Observing, measuring

OBJECTIVES:

1. After making appropriate observations and measurements at two different locations, one an open area and one a wooded area, you will be able to describe the environment of the area in terms of temperature, soil moisture, relative humidity, wind direction, and relative wind speeds.
2. Using the data collected, you will be able to contrast different environmental conditions in an open area and a wooded area and attempt to give reasons for the differences.
3. After consulting the references cited below, you will be able to measure relative humidity, wind direction, and wind speeds.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Sling psychrometer
2. Wind gauge
3. Wind vane
4. Victor, Edward, Science for the Elementary School, 3rd ed.
5. SCIS, Environments, Teacher's Guide
6. SCIS, Communities, Teacher's Guide
7. SCIS, Ecosystems, Teacher's Guide
8. SAPA 21, Weather, Teacher's Guide
9. Thermometers, dowel rod, stick, 30 cm ruler, meter stick, protractor, tagboard or cardboard, string, cooking oil, sixteen- or eighteen-gauge copper wire, nails, 15-cm piece of board, long human hair, compass, soil spade

FINAL ASSESSMENT:

1. See objectives above.
2. Bring neatly kept record sheets.

PROCEDURE:

Find two different testing sites, one in an open field and one in a wooded area. Draw a map with a meaningful key so that the location of the two spots which you chose are quite apparent to the instructor. Make the following determinations at each of the three locations three times a day.

A. Record the temperature at both locations in the morning, at noon, and in the evening. Specify the exact times on your data sheets, and be sure that the three times are separated from each other by at least 3-4 hours. Your data sheet on temperature will then look as follows:

Data Sheet on Temperature

Location A:

Morning: (Specify time)
a) Air temperature (1 m. up) =
b) Surface temperature =
c) Ground temperature (3 cm. down) =
d) Sub-soil temperature (20 cm. down) =

Noon: (Specify time)
a) Air temperature (1 m. up) =
b) Surface temperature =
c) Ground temperature (3 cm. down) =
d) Sub-soil temperature (20 cm. down) =

Evening: (Specify time)
a) Air temperature (1 m. up) =
b) Surface temperature =
c) Ground temperature (3 cm. down) =
d) Sub-soil temperature (20 cm. down) =

NOTE: When you take your sub-soil temperatures, use a dowel rod to make the hole for your measurement.

B. Record the soil moisture by using the following scale to help you:

1. Dry soil - falls apart and sifts between fingers
2. Slightly moist - appears moist but does not stick together when squeezed
3. Moist - sticks together in a clump when squeezed
4. Very moist - water is obvious when clump is squeezed
5. Wet - water drips from the clump

Your data should include:

1. Surface soil moisture
2. Ground soil moisture (3 cm. down)
3. Sub-soil moisture (20 cm. down)

C. Wind Measurements:
Determine the direction of the wind and the speed of the wind at both locations. Consider the following questions:

1. Where are the strongest winds?
2. Where are the weakest winds?
3. Is the wind in the same location different at different times of the day?
4. Is there more wind at 60 cm. above the ground than at 15 cm. above the ground? Is there more wind at 2 m. above the ground than at 15 cm. above the ground?

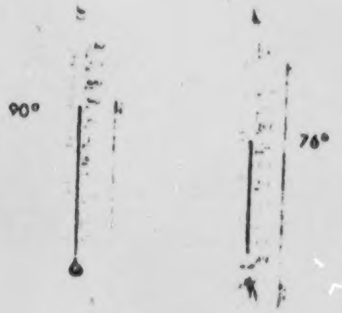
For this activity, you may make a wind gauge of your own design, or you may use the one in the laboratory.

D. Relative Humidity:
Record the humidity at each of the areas three times a day. You may construct a hygrometer of your own design if you wish to do so, or you may use the sling psychrometer in the laboratory.

E. After collecting the data, students should attempt to explain the differences in environmental readings obtained at different locations.

Dry-bulb Reading	Difference between Dry-bulb and Wet-bulb Readings (Fahrenheit Degrees)																	
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°
64°	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30	26	22	18
66°	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32	29	25	21
68°	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	31	27	23
70°	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25
72°	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38	34	31	28
74°	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39	36	33	29
76°	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41	38	34	31
78°	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33
80°	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35
82°	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45	42	39	36
84°	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46	43	40	37
86°	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47	44	42	39
88°	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48	46	43	40
90°	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41
92°	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	48	45	42
94°	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46	43
96°	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44

If the dry-bulb thermometer reads 90 degrees and the wet-bulb reads 14 degrees lower, the table shows that the relative humidity is 52 per cent



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MOD 282 Ratio, Proportion and Percentage

The purpose of this MOD is to develop and enhance your understanding of ratios, proportion and percentage.

OBJECTIVES:

At the conclusion of this MOD you should be able to:

1. Interpret fractions as ratios and vice versa
2. Solve ratio equations
3. Use cross products to find the missing member of a proportion
4. Change fractions to decimals and then to percents
5. Change percents to decimals and then to fractions
6. Find a fraction or percent of a number
7. Find percentage rates of increase or decrease of varying quantities
8. Solve percent equations

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Heath Mathematics elementary textbook, grade eight, pp. 162-191.
2. A First Program in Mathematics by Heywood, pp. 343-410.
3. Houghton, Mifflin Mathematics elementary textbook, grade eight, pp.98-114 and pp. 172-190 and pp. 270-275
4. A First Course in College Mathematics by Willerding, pp. 194-237

PROCEDURE:

1. Review ratio, proportion, fractions, decimals and percents in one or more of the references cited above.
2. Work the problems on the accompanying worksheets. Do this work on your own. Then compare your results with those of your partner or another person working on this MOD.
3. After completing the worksheets to your satisfaction, prepare for a written examination.

FINAL ASSESSMENT:

Ask the instructor or secretary for the test for MOD 282.

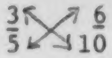
Worksheet

A RATIO compares two numbers. This may be expressed in several ways. Suppose you are comparing five and two. You may write "5 to 2" or "5:2" or "5/2." Each one is read "the ratio of five to two."

Express the following ratios in terms described above.

1. The ratio of x to 3
2. The ratio of 9 to 36
3. The ratio of yellow squares to red squares
4. The ratio of 32 kilograms to 14 kilograms
5. The ratio of your height (in cm) to your weight (in kg)

A PROPORTION is an equation stating that two ratios are equal. For instance, 3/5 = 6/10 is a proportion. In this particular example the cross products are 3 x 10 and 5 x 6.



It is true in this case that 3 x 10 = 5 x 6. If a proportion is true, then the cross products are equal. Next, consider the proportion 2/9 = 4/11. Is this proportion true? Why or why not? No, because 2 x 11 ≠ 9 x 4, is it? Using the fact that cross products are equal in a true proportion, find the missing value in the proportions below. One example is completed for you.

1. 3/4 = x/12, 3 x 12 = 4x, so 36 = 4x, which means x = 9.
   Thus we have 3/4 = 9/12.

2. 5/3 = x/9

3. 2/3 = a/21

4. 6/48 = 8/y

5. 18/a = 12/10

A RATE is a ratio of two quantities, where a quantity is a number of units, not merely a number.
If a person bicycles 23 km in one hour, his rate is 23 km/1hr. If another person travels 51 Km in two hours, his rate is 51 km/2hr.
If a dozen doughnuts cost $1.30, then their cost rate is 12 doughnuts/$1.30.

Proportions may be used to solve rate problems. For example if one gallon of paint will cover 375 square feet of area, then how many gallons are needed to paint 1800 square feet? We can answer this question by setting up a proportion as follows.

$$\frac{\text{1 gal.}}{\text{375 sq. ft.}} = \frac{\text{x gal.}}{\text{1800 sq. ft.}}$$

Next, solve for x by finding the cross products, i.e.

1 x 1800 = 375x, so x = 1800/375 or x = 24/5. In other words 24/5 or 4 and 4/5 gal. of paint are needed to cover 1800 sq. ft.

Solve the following rate problems using proportions.

1. If candy sells at the rate of three bars for 50¢, then how much will 20 bars cost?

2. If Donna earned $5.75 for 4 hours of babysitting, then at that rate what should she charge for 3 hours of babysitting? Round off your answer to the nearest cent.

3. If the speed limit is 55 mph and you drive for 5 hours at the speed limit, then how far will you drive in 5 hours?

4. If Paul read 56 pages in 45 minutes, then at that rate, how long will it take him to read an 845-page book?

<u>To change a fraction to a decimal</u> simply divide the denominator into the numerator. For instance, to change 44/97 to a decimal, divide 97 into 44 like so: (or use a calculator)

```
       .4535    to the nearest ten-thousandth
   97 )44.0000
       38 8
        5 20
        4 85
          350
          291
           590
```

<u>To change a decimal to a fraction</u> simply express the decimal fraction as an ordinary fraction with numerator and denominator, like so:

$1.093 = \frac{1093}{1000}$ or first think of 1.093 as 1 and 93/1000 and then convert the mixed fraction $1\frac{93}{1000}$ to 1093/1000.

Another example of this: .75 = 75/100 or in reduced terms .75 = 3/4

Another example: .00059 = 59/100,000

Work the problems listed on the next page.

Change the following fractions to decimals.

1. 3/7
2. 3/2
3. 7/10
4. 3/500
5. 5/240
6. 7/9
6. 1/12
7. 3/8
8. 1/6
9. 2/11
10. 235/750

Change the following decimals to fractions.

1. 0.59
2. 1.75
3. 0.375
4. 0.0032
5. 1.2
6. 0.80
8. 0.143
9. 45.0
10. 3.49

To change a decimal to a percent simply move the decimal point over two places to the right and attach a percent sign. For example, .29 = 29.%

To change a percent to a decimal simply drop the percent sign and move the decimal point (maybe not actually shown) two places to the right. For example, 73% = .73

Thus to change a fraction to a percent, first change the fraction to a decimal and then change the decimal to a percent.

Vice versa, to change a percent to a fraction, first change the percent to a decimal and then change the decimal to the fraction form.

Fill in the blanks below.

Fraction	Decimal	Percent
1/8	______	______
5/12	______	______
5/6	______	______
______	1.25	______
______	.085	______
______	______	48%
______	______	$16\frac{2}{3}\%$
______	0.05	______

Now, let us consider finding a fraction or percent of a number.

"1/3 of a liter" "40% of the cars" "1/2 of a mile"

These are all expressions like which you have probably heard frequently. How do you interpret them? For instance, 1/2 of $1.00 we know to be $0.50 so 1/2 of (any quantity) is simply 1/2 times that quantity. Similarly, any fraction of a quantity is merely that fraction times the quantity, i.e. 1/3 of 21 is 1/3 x 21 or 7. Likewise, a percentage of a quantity is simply that percentage times the quantity, i.e. 40% of 1,500 is the same as 0.40 times 1,500 or 600. Based on these examples and the above discussions solve the exercises at the top of the following page.

1. 5/2 of 18 oz. is ______________
2. 9/8 of 7.3 is ______________
3. 24% of 32 in. is ______________
4. 125% of 91 is ______________
5. 3/4 of $59.95 is ______________
6. A gallon of a certain kind of paint will cover 425 square feet. How many square feet will 2/3 of a gallon cover?
7. In a survey of 96 employees, 30% of those surveyed commute more than 10 miles to their jobs. How many workers live within 10 miles of their jobs?

Solving percent equations usually involves finding a percent of a number. For example, if a company gives its employees a 13% raise, what raise would an employee expect who now earns $9800 annually? Here are three ways of considering this problem.

1) $\frac{13}{100}$ of \$9800 = $\frac{13}{100}$ x \$9800 = \$1274

2) Solve by multiplying by the equivalent decimal.

$$\begin{array}{r} \$9800 \\ \underline{.13} \\ 29400 \\ \underline{9800} \\ \$1274.00 \end{array}$$

3) Solve by solving a proportion.

$$\frac{13}{100} = \frac{x}{9800}$$

$$\begin{aligned} 100x &= 13 \times 9800 \\ 100x &= 127{,}400 \\ x &= 1274 \end{aligned}$$

So the raise will be $1274.

Solve the following problems.

1. 50% of 348 is ______________
2. 23% of 97 is ______________
3. 8¼% of 153 is ______________

Now consider finding the number when you know a fraction of the number.

Suppose you know that 3/4 of a certain number is 15. How shall we find the number? Call the number "n."

$3/4$ of n is 15 or
$(3/4)\ n = 15$
So $4(3/4)\ n = 4(15)$
or $3n = 60$
Then $n = 20$. Thus n is 20.

Or we could have solved by multiplying by 4/3 on both sides of the equation $(3/4)n = 15$, like so:

$$\frac{4}{3}\left(\frac{3}{4}\right) n = \frac{4}{3} \times 15$$

So $n = 60/3$ or 20.

Solve the following problems.

1. $5/8$ of $a = 25$

2. If the sales price of a belt is$4.80 and the sales price is 2/3 of the regular price, how much is the regular price?

3. A campus club raised 40% of the money needed for a club trip. If the club raised $72, then how much money is needed for the trip?

We may solve percent problems like the above by setting up ratios also. Consider the example at the very top of the page. We could solve by saying 3:4 as 15 : n i.e.

$\frac{3}{4} = \frac{15}{n}$ Then solve by cross products.

$3n = 60$
and $n = 20$

Solve the three problems above using ratio equations, i.e. proportions.

Another aspect of solving percent equations is finding what percent one number is of another. For example, suppose in a basketball game a player makes 14 successful shots out of 39 attempts. What percent of his shots did he make?

Method 1) Using a proportion:

$$\frac{14}{39} = \frac{x}{100}$$

Find the cross products.

$$1400 = 39x$$

$\frac{1400}{39} = 35.89$ or about 36% is our answer.

Method 2) 14 is x% of 39

$$\text{So } 14 = \frac{x}{100}\ 39$$

$$\frac{100\ \ 14}{39} = x$$

$$35.89 = x$$

In solving "percent increase" or "percent decrease" problems, first find the amount of increase or decrease. Then find the ratio of that amount to the original quantity, not necessarily the largest or the smallest quantity. For example, suppose Mr. Nader's salary was $12,400 last year. After a raise, his salary was $14,000. What percent was his salary increase?

First, find the amount of increase. This is $14,000 - $12,400 or $1600.

Then compare this amount to the original salary: $\frac{1600}{12,400}$

and convert this to a percent.

$\frac{1600}{12,400} = \frac{4}{31}$ or .1290 (to the nearest ten-thousandth) which is 12.9%

Solve the following problems.

1. 14 is what percent of 35?
2. 38 is what percent of 19?
3. A store manager bought an item for $63.75 and sold it for $89.00. What was his percent of "markup"? Give the answer to the nearest cent.
4. Consider the table below. What was the percent of decrease in the population of Chicago between 1950 and 1970?

City	Population in		
	1950	1960	1970
Detroit	1,849,568	1,670,144	1,513,601
Chicago	3,620,962	3,550,404	3,369,359
Los Angeles	1,970,358	2,479,015	2,809,596

MOD 283 Ice Cubes
Experimenting

OBJECTIVES:

1. Given ice, freezer, thermometer, specified liquids, solids, and containers, you will make empirical investigations regarding the following questions:
   a. How can you increase the rate at which ice melts?
   b. How can you best preserve an ice cube without a freezer?
   c. Does the shape of an ice cube affect its rate of melting?
   d. What happens when different types of solid objects are put on top of ice?
   e. How cold can you make a sample of water?
   f. Can you, with water, produce a temperature lower than water's freezing point?
   g. How do the densities of water and ice compare?
   h. How does the density of alcohol compare to that of water and of ice?
2. You will formulate at least two good questions regarding the phenomena encountered in your investigations and formulate an answer to at least one of your questions.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Ice Cubes, Teacher's Guide
2. Freezer, thermometers, ice, water, alcohol, salt, sugar
3. Containers of various sizes and shapes, coins, tacks, other miscellaneous small solid items

FINAL ASSESSMENT:

1. Bring to your instructor the record of your investigations, and be prepared to discuss them.
2. See objective 2.

MOD 284 Heredity, Part I: Traits, Genes, and Alleles

OBJECTIVES:

1. Define and distinguish where possible between the terms: gene, allele, trait; dominant, partially dominant, recessive; phenotype, genotype; homozygous, heterozygous; multiple alleles; self cross, back cross.
2. Design an experiment to test whether an allele is dominant or recessive.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on Heredity.
3. Biology Media instructional materials.
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.

INTRODUCTION:

In 1865, Gregor Mendel presented the results of several years of experiments in breeding pea plants. Mendel had conducted his experiments in an attempt to find general rules that might govern ways in which characteristics are passed from parents to their progeny -- rules that might hold for all species. This was an ambitious project, particularly since most scientists at that time did not believe that such general rules could exist, in view of the apparent diversity of reproductive methods among different life forms. Nevertheless, Mendel's results did lead to a set of new and unique concepts. The most basic of these concepts was the idea that there are unit characteristics (traits), each of which is controlled by its own stable internal factor (a gene). Equally important, perhaps, was the discovery that inheritance of these factors could be analyzed, described, and predicted, using mathematical principles of probability and statistics.

Mendel's report was a quiet start for such a revolutionary discovery. Mendel alone realized the importance of his work. No other scientist appreciated its potential. Even Mendel never learned how widely his concepts might apply to other species. It was only in 1900, sixteen years after Mendel's death, that three scientists independently discovered his paper, repeated his work, and led a host of biologists in developing and extending his ideas.

Mendel developed his principles with absolutely no knowledge about the chemical basis on which genes function. Now, even though we know a good deal about the chemistry of genes, we still find Mendelian analysis of heredity useful for predicting the results of controlled (and uncontrolled) matings. Mendelian principles are also essential for developing a genetic explanation for the mechanism of evolution.

THE PURPOSE OF THIS MODULE IS: (a) to introduce and describe the Mendelian concepts of a gene; (b) to describe patterns of expression (dominance, partial dominance, recessiveness) of different forms (alleles) of genes; (c) to describe the rules that govern the inheritance of single genes in higher plants and animals. But especially, this module is designed to introduce the types of problems in genetics that Mendelian analysis can solve.

① HEREDITY, PART I: TRAITS, GENES, AND ALLELES

Most of us take for granted the basic principle of heredity: that an organism's children will look very much like that organism and its mate. ② The offspring of two giraffes will be a giraffe, ③ or two rhinoceroses will be a rhinoceros cub or colt or whatever, ④ and two redwood trees will have another redwood. All this is easy to predict when the two parents look the same. But what happens when the parents are different/ What do the pups look like when a German shepherd mates with a collie? What happens when a blue Persian cat mates with a Siamese? Is it possible to cross wheat with rye; and if so, what would the resulting grain look like? Intuition doesn't give us good answers to questions like these.

As complicated as the study of heredity may be, there are a few simple rules that can explain how many characteristics in many species are transmitted from generation to generation. It is the purpose of this module to describe some of these rules and how they are used. Remember, you can stop the tape at any point if you need more time to study a slide or think about an idea that has been presented.

⑤ Let's simplify the problem. We will consider only one species of organism: the common garden pea plant. We want to be able to mate different strains of peas and observe how their characteristics mix in their offspring. In order to do this, we must meet certain conditions: first, we must have characteristics that we can easily see, measure, and use to distinguish one strain of pea plant from another. ⑥ Peas have several of these: for instance, height -- a strain is either short (about 12 inches) or tall (4 to 6 feet); flower color -- a particular strain has either red or white flowers; or seed shape -- a particular strain has either round or wrinkled seeds. These unit characteristics -- height, flower color, and seed shape -- are called *traits*. Notice that pea plants have very many traits, including ones that do not vary from strain to strain, like possesion of roots, green color of leaves, etc. The traits that we will find useful for studying, though, are the ones that have alternative forms in different strains, like red and white flowers, short or tall stems, etc.

⑦ Second, we need strains that can be described in terms of traits: short plants with red flowers and round seeds, or tall plants with red flowers and wrinkled seeds, for instance. It is especially important for our experiments that these original strains "breed true"; that is, that their progeny always have the same traits that they do.

Finally, in order to study the inheritance of traits, we must understand and be able to control the reproduction of the pea plants. That is, we must be able to mate different strains of peas and know which parents produced which seeds. This is easy. The organs of reproduction in pea plants are their flowers. ⑧ Now I am going to give you some terminology to describe how sexual reproduction occurs in pea plants. ⑨ It is not necessary for you to memorize all of the names of the flower parts, but it is important that you understand which parts of the flower are male and which are female and, in general, how the progeny generation is formed at fertilization.

The flower produces pollen grains that contain the male gametes, or sperm cells; and ovules that contain the female gametes, or egg cells. The sperm cells and the egg cells contain all the genetic information about specific traits that the new generation will inherit. Pollen is produced in tiny anther sacs at the end of the stamens, and ovules are produced in the ovary at the base of the pistil. When pollen is placed on the end of the pistil, each grain produces a pollen tube that grows down the pistil carrying the sperm to the ovules in the ovary. A pollen tube grows into each ovule and releases the sperm which fertilizes the egg cell in that ovule. The product of this union of sperm and egg cells is the zygote, the first cell of the new progeny generation. The zygote grows into an embryo, and the ovule with its embryo becomes a seed -- a pea seed. Pea seeds, when planted, grow into progeny plants. It is easy to place pollen from one strain of peas on the pistil of another strain by hand, then isolate the pollinated pistil (for example, by tying a bag around it) so that it cannot be repollinated either by its own pollen or by pollen from another unknown strain. Thus we can control the parentage of the seeds that develop.

⑩ Gregor Mendel, who first worked with peas, realized that these factors are necessary for the genetic analysis of any organism:

(a) simple, distinguishable traits with alternative forms in different strains;
(b) original tru-breeding strains;
(c) and a controllable system for sexual reproduction.

Since we have found an experimental system that meets our three conditions, we can proceed to the first experiment. Again, we will simplify the situation, this time considering just one trait and ignoring whatever happens to the other traits. We will start out with stem length, or height, of the plants.

⑪ First we mate a tall strain of peas with a short strain. We do this in two ways. First, we use pollen from the tall strain to fertilize the egg cells in the ovules of the short strain; then we reverse the experiment and use the pollen from the short strain to fertilize the egg cells of the tall strain. In either case, the result is the same. The seeds from this mating all grow into tall plants. In the second stage of our experiment we mate these tall plants (the new hybrid generation) with each other. The seeds they give in every case grow into a mixture of tall and short plants. In fact, in both of our experiments, if we look at a large number of seeds of this third generation, we see about three tall plants to every short one.

What conclusions can we draw from this experiment? Did male and female parents influence the traits of their progeny to the same degree? They must have, for if they did not, the two halves of the experiment would have given different results. Are the tall and short traits of equal weight in determining the height of the progeny? Apparently not. For some reason, the tall trait seems to appear more often that the short in the progeny. Does the short trait then disappear when mixed with the tall trait? No! A tall plant of the second generation, one of whose parents was short, can have short progeny. That tall plant must have retained some "memory" or determining factor from its short ancestor which it could pass to its offspring.

⑫ After making these kinds of observations, Mendel devised a scheme to explain them. This scheme was hypothetical -- it did not explain everything -- but it had a striking advantage: if true, it promised to predict the progeny that would result from mating many different combinations of parents with various traits. ⑬ First I am going to describe Mendel's scheme and then diagram how it applies to our experiment with tall and short peas.

⑭ Each single trait (said Mendel) like height, flower color or seed shape is determined by its own single gene. A gene is some undescribed factor inside the cells of the organism that produces the trait. ⑮ Traits vary because genes determining these traits vary. The different forms of a particular gene are called alleles. For instance, there are tall alleles and short alleles of the gene in peas that controls height of the plant.

Genes are transferred from each parent (both male and female) to their progeny in their gametes. ⑯ That is, in their sperm or egg cells, as the case may be. An adult starts with two copies of each gene in its body cells. When gametes are produced, a parent donates one copy of each gene to each gamete. Since a zygote -- that is, the new generation -- is formed by the fusion of the male and female gametes at fertilization, it will again have two copies of each gene. When an adult produces gametes, however, it will give each gamete only one of its two copies of each gene. As I said above, traits vary because genes vary. ⑱ The expression of traits is controlled by genes. If an organism has two alleles of the same type -- like two tall alleles -- it will have that trait. But if an organism has two different alleles -- e.g. one tall and one short -- only one allele is expressed. The organism has the trait from one allele.

Now I've got to give you some vocabulary and at the same time apply it to our peas.

⑲ An organism's visible trait (for instance "tall" or "short") or collection of traits is called its phenotype. ⑳ An organism's collection of genes is called its genotype. ㉑ We use symbols to describe the genotype. For instance, the letter "T" can represent the gene for height in pea plants; capital "T" meaning the tall allele and small "t" meaning the short allele. When the organism has two identical alleles (TT or tt), it is said to have a homozygous genotype or to be homozygous for that particular allele. In a homozygous individual, the genotype always matches the phenotype. When an organism has two different alleles (Tt), it is heterozygous. In a heterozygous individual (Mendel's explanation goes) only one of the alleles is expressed. That is, only one of the alleles determines the phenotype. The allele that does is called dominant. The other, unexpressed allele is called recessive. Both the dominant and recessive alleles coexist in a heterozygous individual, even though only one is expressed. We cannot know which allele is dominant, which recessive, until we actually see the phenotype of a heterozygote.

㉒ Now we diagram the genotypes of the parent and progeny pea plants in our experiments. Let's start with our true-breeding strains. Each true-breeding tall plant has two tall alleles, TT, as its two copies of the gene for height. When it is crossed with another true-breeding tall plant, it and its mate each donate one tall allele in their gametes. Their progeny thus again has two tall alleles of the gene for height. There is no chance for the progeny to have a genotype different from that of its parents. Hence, the parents are "true-breeding." Exactly the same is true for the true-breeding short plants, except that their genotype is tt.

㉓ When a tall plant is crossed with a short plant, their progeny must have one tall allele and one short allele -- they must be ㉔ heterozygous. We know that the phenotype of this plant is tall. Therefore, the tall allele must be dominant and the short allele, recessive.

㉕ In the second cross, when the heterozygous tall plants act as parents, they produce two kinds of gametes: gametes with tall alleles, and gametes with short alleles. The combinations of these different gametes result in different genotypes and phenotypes in the progeny. T pollen which is used to fertilize T egg cells gives a homozygous tall progeny; t pollen which is used to fertilize t egg cells gives a homozygous short progeny; and T pollen used to fertilize t egg cells, or t pollen used to fertilize T egg cells, gives heterozygous (tall) progeny

How many of these different kinds of progeny do we expect? This is where the principles of probability come in. Probability is simply a mathematical way of expressing and manipulating our intuitive beliefs about the likelihood of an event. ㉖ Here is a basic definition of probability. In an experiment with n equally likely outcomes, we expect in a large number of trials that any one outcome will actually occur 1/nth of the time. We say that the "probability" of any one outcome is 1/n. ㉗ The experiment may be flipping a coin -- the probability of getting heads or tails is 1/2. Or it may be throwing a die. ㉘ Here are six equally likely outcomes, so the probability of any one occuring is 1/6. ㉙ Apply this to our genetic cross. Mendel said that, in a heterozygous parent, dominant and recessive alleles have an equal chance of being incorporated into gametes. Stated another way; if one chooses a gamete, the chance that it carries a dominant allele or carries a recessive allele is equally likely. Therefore, the probability of ㉚ finding a gamete with a dominant T allele equals 1/2. Also, the probability of finding a gamete with a recessive t allele equals 1/2. If one has to choose two gametes to form a zygote, ㉛ there are four possible outcomes, each equally likely. ㉜ The chart on the slide shows these: TT, tT, Tt, and tt. ㉝ The probability of any one occuring equals 1/4. ㉞

We have just determined that the probability of obtaining a short plant (genotype tt) from this mating of two heterozygotes equals 1/4. The probability of finding a tall plant is the probability of finding either genotype TT or Tt or tT. Each occurs 1/4 of the time. Together they occur 3/4 of the time. ㉟ The probability of finding one of the three is therefore 3/4. Since the probability of finding a tall plant is 3/4, we expect three times as many tall plants as short plants in the progeny from this cross. ㊱ This is exactly what was found.

Thus, Mendel's scheme, which postulated the existence of genes and told how many there were and how they were passed from parents to progeny, explained the results of this first experiment. If that were all it did, however, it would not be particularly interesting. The real value of Mendel's scheme lay in its ability to predict the genotypes and phenotypes of offspring from other, different matings.

㊲ For instance, what progeny are expected in the cross between a true-breeding short pea plant and a hybrid tall plant? Try this problem on your own. Stop the tape and slides, write down the genotypes of the parents as a start, and continue from there. Calculate the proportions of the different genotypes and phenotypes you would expect in the progeny. The answer is on the next slide.

㊳ Here it is. You should expect 1/2 short plants with genotype tt, and 1/2 tall plants with genotype Tt in the progeny. If such a cross were actually performed, and large numbers of progeny scored, the result really would give close to a one-to-one ratio of short to tall plants. This would represent a successful test of Mendel's hypothesis. It is a back cross, because the hybrid was mated with its parent or a plant with the same genotype as its parent. It is also a test cross because it can be used to test whether the tall plant is homozygous or heterozygous.

㊴ Mendel's explanation is also valuable because it can be used with many different traits. Mendel himself showed that it worked with seven traits in peas: seed shape, seed coat color, seed cotyledon color, pod shape, pod color, flower position, and of course stem length or height. For each trait he identified two alleles, found which one was dominant, and demonstrated a three to one ratio of dominant to recessive phenotypes in the progeny from two heterozygous parents.

㊵ Try this problem to test your understanding of the Mendelian concepts. Two pea plants, each with green pods, are mated. Most of the progeny have green pods, but some have yellow pods. Are the progeny with yellow pods homozygous, heterozygous, or a mixture of both? Here is a hint: are the parents homozygous, heterozygous, or a mixture? Turn off the tape and figure out the answer. The answer is on the next slide when you are ready or if you give up.

㊶ O.K. The parents must be both heterozygous. If they were homozygous recessive, then their progeny would all have their phenotype. If they were homozygous dominant (or even if one was homozygous dominant and the other heterozygous) still their progeny would all have the same phenotype as their parents. Thus the parents must both be heterozygous. But the parents have green pods, so the plants with yellow pods cannot be heterozygous. They must be homozygous -- homozygous recessive.

The very best part about Mendel's scheme is that it has now been found to apply not only to pea plants but to many other species of organisms, bot plant and animal. All you need in order to apply it are the three factors we originally mentioned: simple traits, true-breeding strains (originally at least), and a controllable system for sexual reproduction. Cattle have been studied for a long time. The following problems will give you some practice with cow genetics.

㊷ Assume you have two strains of cattle, one of which is horned, the other hornless ("polled"). This difference is due to a single gene which has two alleles. How would you determine which allele is dominant?

The answer? Simply mate a homozygous horned bull with a homozygous polled cow (or vice versa) and observe the phenotype of the offspring. But it is very important that the animals be homozygous, that is true-breeding. Why? What would you do if you didn't know that your strains were true-breeding? I'll leave you this to figure out later. ㊸ It turns out that the polled allele is dominant; the horned allele is recessive.

㊹ A polled bull mates with a horned cow. One calf was horned and one was polled. What were the genotypes of the parents? The answer is on the next slide.

The best way to figure out this problem is to write down all the genotypes, for parents and progeny, that you know. ㊺ Since the horned trait is recessive and the cow has horns, she must be homozygous recessive, genotype hh. The horned calf must also have this hh genotype. The bull and the polled calf must have at least one H (polled) allele, since they both show the polled trait. The question then is whether the bull is homozygous or heterozygous. The logic is easy. ㊻ The horned calf must have received one h allele from the bull as well as one from the cow. Therefore the bull must possess one h allele. Therefore he must be heterozygous, genotype Hh.

㊼ The same bull mates with a heterozygous polled cow. What is the probability that their calf will have horns?

To see the answer most easily, write the gametes from both parents and sketch a square like the one we used for peas. ㊽ Only one out of four possible genotypes in the progeny will give a horned calf. Thus the possibility of a calf having horns is 1/4. What is the probability of a calf from this mating being heterozygous? The square shows that two outcomes out of the four represent heterozygous genotypes: the probability of the calf being heterozygous is therefore 2/4 or 1/2.

㊾ So far we have used the same key concepts to analyze heredity in both plants and animals. To summarize, these concepts are: the ideas of genes and genotype; different allelic forms of a gene; the ability of one allele to dominate another in determining phenotype; the random segregation (distribution) of alleles into gametes, and the random combination of alleles in gametes at fertilization. As I mentioned before, these same concepts can be applied to very many traits in a large number of species. However, as you might imagine, if you look hard enough you can find exceptions to some of these concepts. In the last section of this module I am going to describe a couple of exceptions which I hope will clarify, rather than confuse, this topic of genetic analysis.

First exception: ㊿

For some genes in some organisms, alleles are not necessarily dominant or recessive. Sometimes the phenotype of the heterozygote is intermediate between, or a combination of. or different from the phenotypes of either the homozygous dominant or the homozygous recessive strains. This situation is called partial dominance or incomplete dominance of alleles. Some common examples of partial dominance are found with snapdragon flower color, coat color in cattle and horses, and human blood types. In snapdragons, one allele of a gene for flower color gives red flowers; another allele of the same gene gives white flowers. A heterozygote that has both alleles has pink flowers. In cattle, one allele of a gene for coat color gives a redish coat; another allele of the same gene gives white. The heterozygote is roan colored. In humans, a person with one allele for type A blood and one allele (of the same gene) for type B blood will have type AB blood.

How are partially dominant alleles inherited? Remember that dominant and recessive alleles are inherited, that is, distributed to gametes identically. Whether they are expressed does not influence how they are inherited. The same principle applies to partial dominance. They are distributed to gametes just like dominant and recessive alleles. (51) You can see this easily in the diagram of a cross between two pink snapdragons on the slide. The symbols that we assign to specific alleles are arbitrary and so here we will use RR' instead of Rr to designate alleles controlling flower color in snapdragons. The progeny have genotypes in these proportions: 1/4 RR, 1/2 RR', and 1/4 R'R'. These can be read directly as phenotypes: 1/4 red, 1/2 pink, and 1/4 white. What phenotypes in what proportions would you expect from a cross between white and pink plants?

(52) Here is a more complicated problem. In a flock of chickens there are three different feather colors: blue, black, and white. A cross between blue and black parents gives blue and black chicks. A cross between blue and white parents gives blue and white chicks. A cross between black and white parents gives only blue chicks. Assume that there are two alleles of the feather color gene: C and C'. Which phenotypes (blue, black, white) come from homozygous genotypes? Which from the heterozygous genotypes? Turn off the tape and try this problem. The answer is on the next slide and tape sequence.

(53) Here is the answer: blue is the phenotype of the heterozygote; black and white are both phenotypes from homozygous genotypes. (54) This must be true because only the black and white cross gives a uniform color of chick. Whenever a blue parent participates, there are two colors of chicks. This indicates that the blue parent must be producing two gamete genotypes and therefore that the blue chickens must be heterozygous.

Second exception:

There is no reason why any gene should have exactly two alleles. Many genes -- genes that control traits that do not vary from strain to strain -- are represented by only one allele. Other alleles are possible, but only one is found in nature. Probably only that one allele allows the organism to function successfully. For many genes there are more than two alleles found in nature. Each additional allele often means a new phenotype -- a new apparent form of the trait. (55) An example is seen in the coat color of rabbits. There are three common alleles of this gene: C, c^{ch}, and c. The three alleles represent different degrees of coloring. The possible genotypes and their corresponding phenotypes are shown in the slide. Notice that C is dominant over both c^{ch} and c; also, c^{ch} is dominant over c. The fact that there are three alleles for this gene does not change the other rules of heredity. There are still only two copies of this gene in each rabbit and only one copy in a rabbit sperm or egg cell.

(56) Try this problem on rabbit inheritance. A full-colored rabbit crossed with a white rabbit gave birth to three chinchilla and four full-colored rabbits. What were the genotypes of the parents? Turn off the tape and try for the answer before you listen to the next segment.

(57) The genotype of the white parent had to be cc. That means that the full-color and the chinchilla alleles which showed up in the progeny, had to come from the other parent. Her genotype must therefore have been Cc^{ch}.

Another problem: (58) What offspring, in what proportions, would be expected from the mating of a rabbit with the genotype Cc^{ch} with a rabbit with the genotype $c^{ch}c$? The answer is on the next slide.

By now, whenever you hear a problem like this you should automatically list the gametes from each parent and draw the Punnett (59) square to show combinations of alleles. The square for this mating indicates an expectation of 1/2 full-colored and 1/2 chincilla.

(60) That's all for this module. This has been just an introduction to the concept of genes and alleles. More introduction on the inheritance patterns of several genes observed simultaneously and on the structural basis for gene inheritance is presented in the next module HEREDITY, PART II: MULTIPLE GENES AND CHROMOSOMES.

MOD 285 Heredity, Part II: Multiple Genes and Chromosomes

OBJECTIVES:

1. Define and distinguish between: linkage, recombination, crossover, chiasma; linkage group, chromosome, genetic map; parental type, recombinant type.
2. State a physical explanation for recombination between genes on the same chromosome.
3. Given the genotype of a parent, describe the possible genotypes of its gametes, and calculate the expected frequency of each gamete genotype (two unlinked genes, or two linked genes).
4. Given the genotype of two parents, describe the possible genotypes of their progeny, and calculate the probabilities of each genotype's occurrence (two unlinked genes, or two linked genes).
5. Identify two genes as linked or unlinked, given data on appropriate genetic crosses.
6. Given appropriate genetic information, map the position of three linked genes.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD
2. General Biology references on Heredity
3. Biology Media instructional materials
4. Singer Caramate

FINAL ASSESSMENT:

1. See objectives above.

INTRODUCTION:

Gregor Mendel, in his landmark paper on the genetic analysis of pea plants, did more than simply describe the heredity of single, simple traits. He also performed and analyzed matings in which he followed two or more traits simultaneously. Mendel's studies lead him to propose a rather simple relationship to explain the inheritance of multiple genes. He said that different alleles of one gene were inherited completely independently from the alleles of any other gene.

Mendel's conclusions were correct as far as they went. He had considered only seven traits in peas, and those seven traits in fact do depend on genes that act independently of one another. But after the rediscovery of Mendel's principles, many pairs of traits in many organisms were found that were not inherited independently. The exact pattern of inheritance might depend on which pair of genes was studied, but in general the "non-Mendelian" pairs acted as though they were connected more or less tightly. These gene pairs were called "linked".

If Mendel had worked with connected, or "linked", genes instead of the seven genes that he chose, he might never have deduced any orderly pattern in the relationship between genes. However, events occuring after Mendel's report laid the foundation for the understanding of both independent pairs of genes and linked pairs of genes. These events included descriptions of mitosis and meiosis analysis of diversity of insect chromosomes ... work that lead to Sutton's suggestion that genes were carried by chromosomes. Sutton himself showed that genes on different chromosomes would be inherited independently, and T. H. Morgan later pointed out that genes on the same chromosome would show the linked pattern of inheritance.

Eventually, studies by Morgan and his colleagues demonstrated that linked genes in Drosophila fall into four groups corresponding to the four types of chromosomes in this insect, and provided some of the strongest evidence for the proposition that genes are located on chromosomes.

THE PURPOSE OF THIS MODULE IS: (a) to describe the inheritance of two or more linked genes; (b) to describe the effect of linkage on the inheritance of two or more genes; and (c) to show how chromosomal juxtaposition explains the phenomenon of linkage between genes.

① HEREDITY, PART II: MULTIPLE GENES AND CHROMOSOMES

② In the module HEREDITY, PART I: TRAITS, GENES, AND ALLELES we talked about the inheritance of the alleles of single genes ... like the genes for height or for seed shape in pea plants, and the gene for coat color in rabbits. Looking at genes one at a time was a useful approach for simplifying the concepts of inheritance at the beginning, but it is clear that if we limited ourselves to considering single genes, we would miss many of the answers to the most interesting questions on heredity. ③ For instance, we would not be able to predict how many kinds of progeny would come from two parents that differ in two, three, four, or more traits. And we would never learn why some traits, like height or hairiness in humans, vary so much more and so much more gradually than other traits like flower color in peas.

This module is going to attack the question of the inheritance of several genes considered all at once. Also in this module, we get a bonus: by considering many genes and the relationships between different genes, ④ we will obtain a rough physical picture of genes -- a way of visualizing them as parts of chromosomes. Again, remember you can stop the tape at any point if you need more time to study a slide or think about an idea that has been presented.

⑤ First, let's start by simplifying the question as much as we can. We will ask what happens when we mate strains differing in exactly two traits... and again we will start with Mendel's garden pea plants. Let's look at flower color and plant height. Remember, for flower color there are two alleles -- one for red and one for white flowers. The allele for red flowers is dominant, and the allele for white flowers is recessive. Similarly, for height there are two alleles -- one for tall and one for short plants. The allele for tall plants is dominant over the allele for short plants.

⑥ Here is our first experiment -- making a hybrid from two different true-breeding plants. We mate a homozygous tall plant with red flowers with a homozygous short plant with white flowers. What are the genotypes of the gametes from these two plants? The rule is, a gamete gets one allele from each gene. This is true whether you are watching one, two, or more genes. ⑦ So the gamete from the tall, red plant carries one tall and one red allele. The gamete from the short, white plant carries one short and one white allele. Fertilization combines these gametes, ⑧ and the progeny all have TtWw genotypes. What are the phenotypes of the progeny? When you remember which alleles are dominant, you know that the progeny are tall plants with red flowers. They look like the first parent, but they of course are not the same because they are heterozygous or hybrid for both the height and the flower color genes. As a matter of fact, since the progeny are hybrid for two genes, ⑨ they are called dihybrids.

The next experiment shows an interesting fact. We can get the same progeny, dihybrid tall plants with red flowers, by mating a different set of parents. ⑩ Here the parents are a homozygous tall plant with white flowers, and a homozygous short plant with red flowers. This is really not so surprising. If you study the diagram, you see it follows naturally from the rules by which gametes get alleles and combine them at fertilization to make progeny. It doesn't matter whether the red allele comes with the tall allele or the short allele. The progeny that receives it will have red flowers.

Are you comfortable with these two examples? ⑪ You can see that, as long as the parents are homozygous or true-breeding for all the genes being studied, predicting the genotypes of the progeny is trivial, whether you watch one or more than one gene at a time.

Now we come to a much more interesting question. ⑫ What happens when a dihybrid, like our TtWw pea plant, makes gametes? What genotypes does it contribute when it is mated with another plant?

To find the possible genotypes of the gametes from the dihybrid plant, you must once again remember the rule: each gamete gets one allele of each gene. There are two choices of alleles from the t gene: T and t; and there are two choices of alleles from the w gene: W and w. ⑬ Taken together, there are four different possible genotypes: TW, Tw, tW, and tw. But which ones actually occur? It turns out that for these two genes all of the possible genotypes occur! Not only that, but all the possible genotypes are equally probable! ⑭ All four types each occur one fourth of the time.

⑮ If this dihybrid were mated with another plant, say one that was homozygous recessive for both genes (ttww), a "test cross" or "back cross", then you would find four types of progeny, ⑯ corresponding to the four types of gametes from the dihybrid. There would be tall plants with red flowers, tall plants with white flowers, short plants with red flowers, and short plants with white flowers. If you looked at enough progeny, you would find the four types in about equal numbers because the four genotypes from the dihybrid were equally likely.

To be certain you understand how the system works, try this problem. ⑰ You mate two dihybrid pea plants, both heterozygous for the height and flower color genes. What progeny, in what proportions do you expect? Stop the tape and figure out the gamete genotypes and the progeny genotypes and phenotypes. The answer will be on the next slide.

⑱ Here it is. Did you get it right? There are four gamete genotypes from each parent -- the same ones we had last time: TW, Tw, tW, and tw -- so that gives you a diagramatic Punnett square with 16 spaces. That represents 16 progeny genotypes, each equally likely. Many of these genotypes give the same phenotypes. There are four phenotypes -- the same ones we had last time: tall/red, tall/white, short/red, and short/white. You can find the relative proportions of the phenotypes by counting up the number of genotypes that give each phenotype. You should come out with 9 tall plants with red flowers to 3 short plants with red flowers to 3 tall plants with white flowers to 1 short plant with white flowers.

So far, watching two genes has been pretty simple, right? Forming hybrids from true-breeding parents is straightforward, just like with one gene. And finding the gamete genotypes from the resulting dihybrid plant is not too difficult: you just found what genotypes were possible and learned that they were all equally likely to occur. ⑲ Mendel actually learned this first. It was one of his general principles for explaining heredity. We can say it two ways: "the possible genotypes for gametes from a dihybrid parent are all equally probable" or "alleles from any one gene are placed in gametes independently from the alleles of any other gene." This is sometimes called Mendel's "Law of Independent Assortment."

Can you extend this principle to three genes? Try it with the gene for seed shape in peas. ⑳ The symbols for the seed shape alleles are R, for round, and r, for wrinkled. What gamete genotypes would you expect from a *trihybrid* pea plant -- a plant heterozygous for seed shape and height and flower color? ㉑ Genotype RrTtWw. Stop the tape and work the genotypes out before looking at the answer on the next slide.

㉒ Okay. From a *trihybrid* there are eight possible gamete genotypes. This is true because there are two choices of alleles for the first gene, two choices for the second gene, and two choices for the third gene. The total number of choices can be calculated by multiplying the numbers for each gene: ㉓ (2)(2)(2) = 8.

(*If* there had been three alleles, that is, three choices, for the first gene, and two choices for the other two, then the total number of gametes would have been (3)(2)(2) = 12. *If* there had been two alleles for each of *four* genes, then the total number of different gametes would have been (2)(2)(2)(2) = 16. See the system?)

㉔ Now that you know that there are 8 different gamete genotypes from the trihybrid, the problem is to find them. You can use any system you want. If you look at the list on the slide, maybe you can figure out the one I used. Once you know the possible gamete genotypes, then of course, according to Mendel's principle, each genotype is equally likely.

Now we come to an extremely important point. We have talked about the formation of gametes from dihybrids and trihybrids, etc., and we have learned Mendel's statement on the subject: ㉕ that the possible genotypes are all equally probable, or that the alleles from any one gene are placed in gametes independently of alleles from other genes. Does this mean that *all* genes in *all* organisms work this way? Unfortunately, no! In the organisms which we have been studying -- peas, cows, rabbits, chickens, humans -- there are *some* pairs of genes that do follow Mendel's rule. And then there are some pairs of genes that do not. Mendel himself picked seven genes in peas; all pairs of which do follow the rule; do distribute into gametes independently of one another. It was a good thing for his peace of mind. If he had picked another set, he might have been hopelessly confused.

When a pair of genes does follow Mendel's rule, ㉖ when the alleles do distribute into gametes independently, then the genes are called unlinked. When all the four possible genotypes of gametes from a parent heterozygous for two genes occur with equal probabilities or frequencies, then the two genes are unlinked.

㉗ But for some pairs of genes, two of the four possible gamete genotypes occur more often than the other two. That is, the four possible genotypes are not equally probable. The two genes do not seem to distribute their alleles to gametes independently of each other. Instead, two pairs of alleles tend to move into gametes together. When this occurs, the two genes are said to be linked. When certain genotypes of gametes from a parent heterozygous for two genes occur more often than the other genotypes, then the two genes are linked.

Sometimes, for some pairs of genes, two gamete genotypes occur all the time; the other two possible genotypes never occur. Then the genes are "tightly' linked, or "closely" linked, or "completely" linked. Sometimes, for other pairs of genes, two of the gamete genotypes occur, not all the time, but a bit more often then the other two genotypes. Then the genes are "loosely" linked, or "incompletely" linked.

Here is an example of linked genes in peas. ㉘ The genes are for seed shape (R = round; r = wrinkled) and for possession of tendrils (TN = tendrils present; tn = tendrilless). ㉙ A plant ㉚ heterozygous for the two genes was mated with a plant homozygous recessive for both genes. The dihybrid produced only two kinds of gametes -- not the four equally-frequent kinds of gametes you'd expect if the genes were unlinked. You know the dihybrid produced only two kinds of gametes because there were only two kinds of progeny produced: tendrilled plants with round seeds, and tendrilless plants with wrinkled seeds. Since the dihybrid gave only two kinds of gametes, the genes must be linked.

㉛ How are you supposed to know whether a pair of genes will be unlinked, tightly linked, or loosely linked? There is no way to tell from just knowing what the traits controlled by the two genes are. The only way to find out is to do the appropriate experiment: to mate an individual who is heterozygous for the two genes you are concerned with, and find out from the progeny what kinds of gametes it produces.

Does it seem to you that this topic of the inheritance of multiple genes has all of a sudden gotten out of hand? Does it seem that a simple rule like Mendel's might be useful, but that all the exceptions -- the linked genes -- make the subject incomprehensible? I don't blame you if it does. What you need is a picture of genes, a visual image , something to help you straighten out the difference between linked and unlinked genes, let you keep different alleles of the same gene in order. Fortunately, I can now give you a picture that will not only help you figure out genetics problems, but that also is fairly accurate ... that will tell you what genes (or at least the carriers of genes) really look like in the cell.

㉜ The organelles that carry genes within the cell are the chromosomes. You have seen descriptions of chromosomes in the cell cycle modules. They are usually long, thin bodies with a constricted place, the centromere, in the center or at one end. They are in the nucleus. They are visible as discrete structures only around the time of cell division. ㉝ There are two chromosomes of each type in each cell of every adult (either parent or progeny generation). The two chromosomes, or pair of chromosomes of one type, are called homologous. These two chromosomes of the same type correspond to the two copies of each gene that are found in the adult.

㉞ We might start to diagram a pea plant cell by showing just the two chromosomes that both carry the gene for height. If the plant were heterozygous, one chromosome would carry a tall allele and the other would carry a short allele.

If you have studied Mitosis and Meiosis, you know how regularly the chromosomes are distributed to daughter cells in the course of cell division. ㉟ In mitosis -- this is the regular, everyday cell division that occurs in body cells that are not going to become gametes -- the chromosomes are reproduced and then divided so that each daughter cell comes out with one copy of every single chromosome. That is, each daughter cell has the same number and the same type of chromosomes that its mother cell had. If you think about this, you'll see that this explains why every cell has the same two copies of every gene; why, for instance, every cell in our pea plant is heterozygous for height.

There is only one chromosome of each type in a gamete, just as there is only one copy of each gene in a gamete. (36) This is possible because meiosis -- the type of cell division involved in the formation of gametes -- separates the two chromosomes of each type, and places only one in each daughter cell. Each daughter cell has half the number of chromosomes that its mother cell had. Since each gamete gets only one chromosome of each type, it also only gets one copy of the gene that that chromosome carries. Half the gametes from our heterozygous pea plant would get the chromosome with the tall allele for height; half would get the chromosome with the short allele.

Now, so far we have diagrammed the pea plant cell as having only two chromosomes, but actually it has many more. (37) This is an important point, because genes on different pairs of chromosomes are unlinked. When the two copies of one gene are carried by one pair of chromosomes (one pair of the same type), and the two copies of the other gene are carried by another pair of chromosomes, the genes are unlinked. As an example, in our pea plant, (38) the genes for height and for flower color were unlinked. Now we will diagram the pea plant cell with two pairs of chromosomes: one pair (the first pair) carrying the gene for height, and the other pair carrying the gene for flower color. Actually, peas have seven pairs of chromosomes, but we prefer to keep the other chromosomes in the background to simplify the diagram.

(39) You already know that at meiosis, when gametes are formed, the two chromosomes of a given type separate ... each goes to a different gamete. You can also tell from this diagram that different pairs of chromosomes seem quite separate, quite independent. It wouldn't surprise you to learn that the way the first pair of chromosomes separates at meiosis does not affect the way the second pair

of chromosomes separates. Our pea plant is heterozygous for both height and flower color. If, at the first division, the top daughter cell in the diagram gets the chromosome carrying the dominant allele for height, then it may also get either the chromosome carrying the recessive allele for flower color or the chromosome carrying the dominant allele for flower color. That is because the chromosomes carrying the gene for height have no influence on the chromosomes carrying the gene for flower color. You can see both situations -- T with W, and T with w -- in the upper and lower patterns labeled "1st way" and "2d way". The first way and second way are distinct possibilities at the beginning of every meiosis; and they are equally probable. Now notice that the first way gives two gamete genotypes; the second way gives two other gamete genotypes. After a large number of meiotic cell divisions, some going the first way and some going the second way, you would find all four gamete genotypes ... all equally frequent. It seems very reasonable, doesn't it, to see the unlinked genes as being carried by different types of chromosomes.

Okay, our chromosome model explains the inheritance of unlinked genes pretty well. How about linked genes? ㊵ You probably guess the answer already. Linked genes are on the same pair of chromosomes. Consider our pea plant example for the linked genes: (4-) seed shape and possession of tendrils. Two alleles, one for each of the genes, are on one chromosome. The other two alleles for these genes are on the other member of the chromosome pair. The two alleles on any one chromosome look connected -- they look linked. So it is no surprise that those two alleles -- say the TN and R alleles in this diagram -- came from one parent originally, and in the next meiosis they will be placed in another gamete together. The next diagram (-2) shows a meiotic division from this pea plant with the two types of gametes that are formed: two types of gametes from this dihybrid rather than the four types we got in the height/flower color dihybrid example above. We said before that if you found two types of gametes from a dihybrid, the two genes involved were linked. Now you can see why. The two types of gametes come from the separation of one pair of chromosomes at meiosis.

Of course, there must be lots of genes on each type of chromosome. That's the only way to fit many genes in a nucleus with only a few chromosome pairs. This means that there are lots of pairs of linked genes for every chromosome type. For instance, this chromosome that carries the TN and R genes also carries many other genes and gene pairs.

Here are some problems to work to make certain you understand the chromosome model for visualizing genes.

㊸ A certain pea plant is a trihybrid ... that is, heterozygous for three genes: flower color, seed ahape, and possession of tendrils. The first trait is unlinked to the other two, but the second two are tightly linked to each other. This slide shows a diagram of the relevant chromosomes in the plant cells. How many different kinds of gametes, in what proportions would you expect from this plant? What would be their genotypes? Stop the tape and write down the genotypes of the gametes and the relative proportions you would expect. The answer is on the next slide.

㊹ Here it is. You expect four different types of gametes, I hope. That is because there are two choices for the first chromosome, and two choices for the second chromosome. Since one of the chromosomes carries two genes, you don't get separate choices for those genes. The possible genotypes are WtnR, WTNr, wtnR, and wTNr, and they should appear in about equal proportions ... that is, about 25% each.

㊺ Another organism hybrid for three genes (AaBbCc) produced the gametes shown on the slide. Which of the genes are linked? Which are not linked? Draw a picture diagram of the chromosomes in a cell of the adult organism. The answer is on the next slide/tape sequence.

To answer this question, you inspect the genes two at a time and look for patterns. Does one allele of gene A always appear with the same allele of gene B? With a certain allele of gene C? Does one allele of gene B appear with only one allele of gene C? seen this way, the question is easy to answer. The dominant allele of A always appears with the recessive allele of B, so genes A and B are linked. However, the dominant allele of A appears with both the dominant and recessive alleles of C, so A and C are not linked. ㊻ The diagram thus shows genes A and B on one type of chromosome pair and gene C on another type of chromosome pair.

㊼ A final question. What is the difference between the two pea plant cells shown on this slide? Did they come from the same plant? If not, what is the difference between the two plants? Stop the tape and try to answer these questions before looking at the answers on the next slide.

The answer to this question is interesting because it shows a new way in which an individual's phenotype may not reveal his genotype or ancestry. The two cells come from a plant or plants with exactly the same phenotype: the phenotype of having tendrils and round seeds. The plant or plants would be heterozygous for both traits. ㊽ How do you know whether there was one plant or two? The chromosomes are quite different in the two cells: in one cell, the dominant alleles are together on the same chromosome; in the other, the dominant alleles are on different chromosomes. Therefore, the two cells must have come from different plants, ㊾ and those two plants must have had different parents. Here is a slide showing the genotypes of the parents of the two plants.

As I said, the two plants discussed in this last problem had exactly the same phenotype, and in a way, the same genotype. But the two plants would really differ in the way they passed alleles to progeny ... that is, in the gametes they produced. ㊿ One plant would make primarily gametes with the genotypes TNR and tnr; the other plant would make primarily gametes with the genotypes TNr and tnR. (51) Combinations of alleles that are associated on the same chromosomes are called "parental" combinations. For instance, for the first plant, the parental combinations of alleles are TNR and tnr. For the second plant, the parental combinations are TNr and tnR. Sometimes it is useful to be able to give the parental combinations of alleles in a dihybrid, so geneticists have developed a system of notation that can do this. (52) Instead of indicating the genotype by simply listing the alleles, they indicate the genotype by drawing a sort of diagram of the chromosomes. Alleles that are on one chromosome are on the top of the double line; those on the other are on the bottom. The alleles for any one gene are lined up vertically. If there is more than one chromosome involved, they draw separate double lines.

(53) So far, we have seen the meiotic division of one chromosome as a process that would produce only two types of gametes, only

gametes that possess parental combinations of alleles. Looked at this way, the chromosome model explains the inheritance of tightly linked genes just as well as the inheritance of unlinked genes. But in the first section of this module, I mentioned that there is a third possible relationship between gene pairs ... (54) that is, loose linkage. Individuals that are dihybrid for loosely linked genes produce four gamete genotypes, but two of these gamete genotypes are produced more frequently than the other two. This slide, a repeat of one you saw earlier, shows that loose linkege seems intermediate between tight linkage and no linkage at all. But at first glance this doesn't make sense: genes are either on the same chromosome or on different chromosomes. How can there be an intermediate state? The chromosome model must explain this situation if it is to be really useful.

It turns out that the explanation for loose linkage is not too difficult. (55) Loosely linked pairs of genes are on the same pair of chromosomes, just as are tightly linked pairs of genes. The difference comes from this fact: it is possible during meiosis for chromosomes (two homologous chromosomes of the same pair) to exchange alleles. (56) When this is done, the chromosomes lose the parental combination of alleles and carry a new combination of alleles, called a recombinant combination, into the gametes. The parental combinations of alleles are still most frequent and represent the two types of gametes that occur most often. The recombinant combinations of alleles represent the two types of gametes that occur least often. (57) The slide shows the summary of meiotic processes for a mythical cell heterozygous for two genes: AaBb, or $\frac{A \;=\!=\!=\; B}{a \qquad b}$.

In most meioses, there is no exchange between the chromosomes, and the gametes have parental combinations of alleles. In some meioses, there is exchange between the chromosomes, and the gametes have recombinant combinations of alleles. In the lower sequence on this slide, one chromatid of the top chromosome and one chromatid of the bottom chromosome have exchanged alleles of the B gene.

Let's talk about the process of allele exchange a little before we go back to the difference between tightly linked and loosely linked genes. (58) The exchange of alleles is a real, physical process which we can see in a microscope if we watch cells in the early stage of meiosis. In the first stage of meiosis each pair of chromosomes of the same type physically come together and line up so that they lie alongside each other. This is called synapsis. While the two chromosomes are in synapsis, they can touch, both break at the point of touching, and reform with an exchange of ends. The point of touching is called a chiasma (cross). It is not possible to see the breaking and rejoining, but it is easy to prove that it has occurred by labeling one of the chromosomes with a radioactive tag. (59) This slide shows chromosomes that have undergone exchange of parts, although in this particular case the exchange did not occur in meiosis. (There is a complication you may know about. In meiosis, each chromosome has two identical pieces, the two chromatids; so the chromosome pair has four strands, any of which may exchange parts. I'm going to ignore this right now, because it does not affect the points I want to make.)

Now, back to the difference between tightly linked and loosely linked genes. (60) Chiasmata, or crossovers, that lead to exchange of chromosome parts do not occur too often. For instance, there are on the average four crossovers in the Drosophila (or fruitfly) X (sex) chromosome during a meiotic division. The places where crossovers occur are random. Exchange of alleles ... that is, the formation of recombinant combinations of alleles of two genes, occurs only if the crossover is between the two genes. (61) All this means that, when two genes are close together, the chance of finding recombinant combinations of their alleles is small, and the genes will be called tightly or closely linked. (62) When two genes are far apart, the chance of finding recombinant combinations of their alleles is greater, and the genes will be called loosely linked. (63) This diagram shows three genes on one chromosome. Gene A is far from genes B and C: genes B and C are close together. (64) Without crossover, we find the parental combinations of alleles: ABC and abc. It is easy as ABC to see that most crossovers will be between genes A and B. In this case, there will be recombinations of A and B and of A and C alleles, but no recombinations of B and C alleles. Crossovers between genes B and C will be much less likely, but if and when they occur, there will be recombinations between B and C alleles, and recombinations between A and C alleles, but no recombinations between A and B.

In practice, we usually use this relationship backwards: the number of recombinant types of gametes formed shows how far apart the two genes are. The more recombinant combinations of alleles, the farther apart the genes. The geneticists even have a way of quantitating the distance between genes by using this relationship. (65) If the recombinant genotypes in the gametes are 1% of the total number of gametes, then the two genes concerned are 1 "map unit" or "recombination unit" apart. (66) If the recombinant genotypes are n% of the gametes, then the two genes are n "map units" apart.

I want to show you an example in which a mating experiment is used to measure the distance between genes. I will use fruit flies. (67) One of the genes I am interested in is a gene for body color, ebony. The recessive allele for this gene gives a blackish phenotype. (68) This is designated eb. The dominant, or wild type, allele for this gene is designated eb^+. (This type of notation -- eb and eb^+ -- is different from the notation used for other genes; e.g. capital letters and small letters to designate alleles controlling stem height in pea plants. Remember that the symbols we assign to specific alleles are purely arbitrary.) The other gene is a gene that helps control eye color. The recessive allele, when homozygous, gives a maroon eye color. (69) Now here is the experiment: a female fruit fly that was dihybrid for body color and for eye color was mated with a homozygous recessive male. The slide shows the genotypes, and the phenotypes, of the progeny as well as of the parents. There were a total of 1000 progeny counted: 405 with ebony body and wild-type eye, 390 with wild-type body and maroon eye, 97 with ebony body and maroon eye, and 105 with wild-type body and wild-type eye. The first two sets of progeny represented parental combinations of alleles; the second two sets, recombinant combinations of the alleles. The total number of recombinants was 97 + 105 = 202, or about 20% of the number of progeny flies. That means that the two genes, for ebony body color and maroon eye color, are about 20 map units apart.

Here is a problem for you to try. This also concerns fruit flies, but two other genes are involved. One of the genes controls wing shape. (70) A fly homozygous for the recessive allele has vestigial wings ... small wings that look immature. (71) The second gene is a gene for eye color, different from the one we used before in that the recessive allele, when homozygous, gives burnt orange colored eyes. The two genes, vg and buo, are 9.9 map units apart on one chromosome. (72) What progeny genotypes and phenotypes, in what proportions, would you expect when a female, heterozygous for burnt orange eye color and heterozygous for vestigial wing, is mated to the homozygous recessive male? Stop the tape and work out the answer.

(73) Since the two genes involved are 9.9 map units apart, you should expect that 9.9% of the gametes would have recombinant genotypes. The recombinant genotypes are buo vg^+ and buo^+ vg. Progeny from gametes with these genotypes would have burnt orange eyes and normal wings, or normal eyes and vestigial wings. Since there are two types of recombinants, they share the 9.9% occurrence: each would occur at 4.95% of the total progeny. The phenotypes of the progeny from parental type gametes would be burnt orange eyes with vestigial wings and normal eyes with normal wings. Each would occur in 45.05% of the total progeny.

You should be able to work out these linkage problems in both directions: given the number of map units between two genes, and the genotype of the parent, find the genotypes of the gametes and their relative proportions. Or: given the relative proportions of the gamete genotypes, find the distance between the appropriate genes.

By locating a large number of mutants, mating different pairs of mutants, and measuring the number of recombinants for each pair, geneticists can determine the order of all these genes along the chromosome. (74) For instance, we found that the ebony body and maroon eye genes were 20 map units apart on one of the fly chromosomes. The ebony body and the glass eye genes are about 7.5 map units apart; and the glass eye and maroon eye genes are about 27 map units apart. (75) Thus the order of the genes is gl eb ro (or ro eb gl, if you turn the chromosome around). (76) This slide shows a more complete map of this same fly chromosome. The position of each gene in this map was determined by mating mutants of this gene with several mutants of other genes. By determining the position of each gene with respect to at least two others, it could be located exactly on the chromosome. The fact that we can construct maps like this one shows that genes are arranged in a linear order along a chromosome.

If you are sharp, you may have noticed a strange possibility in the chromosome model. As genes get farther and farther apart, the amount of recombination between their alleles increases. How far can this go? If genes are far enough apart, can the recombinants outnumber the parental type gametes? The answer is no. The recombinant genotypes are never more frequent than the parental genotypes. The reason is easy. As the genes get farther apart and the possibility of crossover increases, the possibility that there mat be two crossovers between the genes also increases. And if there are two crossovers between the genes, the gametes will have parental genotypes. If the genes are very far apart, the chance of finding no crossovers, or one crossover, or two, or three, all average out, and the frequency of recombinations of alleles tends to become equal to the frequency of parental combinations of alleles. (77) The situation becomes just like that for unlinked genes. So if two genes are far enough apart on a long chromosome, they will be inherited just as if they were on different chromosomes.

(78) Finally, this is the end of this module. From this module you should have learned the various ways in which pairs of genes can be inherited; and how the position of genes along different chromosomes explains these various patterns of inheritance; and you should have a good idea of how genetic experiments can be used to show the relationship between different genes ... whether they are on the same or on different chromosomes. Good luck with the problems in your program of instruction.

(79)

MOD 286 Heredity, Part III: Sex Chromosomes and Sex Linkage

OBJECTIVES:

1. Describe the chromosomal differences between male and female humans and between male and female fruit flies.
2. Show how the meiotic division of sex chromosomes explains why fruit flies (and humans and other animals) have 50% male and 50% female progeny.
3. Given the appropriate genetic information, tell whether a particular trait is, or is not, sex linked.
4. Explain the heredity of a given sex linked trait in a specified organism by defining the location of the gene for that trait and by stating which alleles are dominant and which recessive.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. This MOD.
2. General Biology references on Heredity.
3. Biology Media instructional materials.
4. Singer Caramate.

FINAL ASSESSMENT:

1. See objectives above.

INTRODUCTION:

The rediscovery of Mendel's experiments on heredity by DeVries, Correns, and Tchermak in 1900 sparked an era of research in genetics. Advances in microscopy in the late 1800s had provided much background information on cell structure and was stimulating searches for structural explanations to basic questions about life. Thus one of the first questions the new geneticists attacked concerned the location and physical nature of genes. Where were they? What did they look like? How did the cell manipulate them during reproductive processes?

An American cytologist, W. S. Sutton, developed the best hypothesis in 1902 by comparing Mendelian principles with descriptions of mitosis and meiosis. Sutton guessed that genes must be attached to chromosomes. Firm evidence supporting this hypothesis appeared in 1910, when Thomas Hunt Morgan, working with Drosophila melanogaster (fruit flies), reported that he could show that a particular allele was associated with a specific chromosome.

Fruit flies (and other animals) have a special set of chromosomes that appear in two forms that can be distinguished in the microscope. These chromosomes are called sex chromosomes, because they seem to determine the sex of the individual that carries them. That is, the sex chromosomes of a male look different from the sex chromosomes of a female. Morgan was able to find a special allele of a gene for eye color and show that it was inherited only by progeny that received a particular sex chromosome, thus proving that the allele must be attached to that chromosome. It was the first clear demonstration that a gene was located on a chromosome.

The concept of genes on chromosomes not only gives physical substance to the idea of the "gene", but also allows geneticists to explain results of matings that violate Mendelian principles.

THE PURPOSE OF THIS MODULE IS: (a) to describe sex chromosomes ... how they are inherited and how they determine sex in animals; (b) to introduce the concept of sex linkage of genetic traits; and (c) to show how the pattern of inheritance of sex linked traits provides evidence that certain genes are attached to sex chromosomes.

① HEREDITY, PART III: SEX CHROMOSOMES AND SEX LINKAGE

Some of the most interesting problems in the world involve sex. Among those that interest geneticists are questions like: why do so many species have as many males as females? Why do most couples tend to have both sons and daughters, but some couples have all sons or all daughters? Whose gene's--the father's or the mother's--determine whether a child will be a boy or a girl? (King Henry VIII spent a lot of time worrying about that one.) Why do some diseases, like hemophilia and muscular dystrophy, seem to occur only in boys?

② The basis for an answer to these questions was discovered around 1900 by cytologists working with insects. Insects are convenient for these studies because they have relatively few chromosomes in the nuclei of ③ their cells. For instance, grasshoppers have 21-22 chromosomes and fruit flies have 8. With these low ④ numbers of chromosomes, it was fairly easy to look during mitosis and meiosis (when the chromosomes were condensed) and see that the shapes of chromosomes followed a definite pattern.

⑤ First, most of the chromosomes occurred in pairs--two members of a pair are called homologous chromosomes, and they look alike. Each pair, however, differs from the others. The characteristics that distinguish the different pairs are, commonly, the length of the chromosome and the position of its centromere. More recently, ⑥ researchers have shown that fluorescent markings can help identify which chromosomes are homologous and which are not.

⑦ Second, there was a difference between the chromosomes in males and those in females. This difference involved only one of the pairs of chromosomes. For instance, among their chromosome complement, female fruit flies had two that were fairly long with centromeres right at the ends.

Male fruit flies had only one of these chromosomes; but in addition the males had an extra, larger chromosome with the centromere about a third of the way from one end. Actually, this extra chromosome looked somewhat like the "female-type" chromosome with an extra piece tacked on the centromere end.

⑧ Let's look at the chromosomes of fruit flies as they are seen in squashed-cell preparations. Notice the three pairs of chromosomes that are the same in both sets. There ⑨ are the largest ones with centromeres in their centers; there ⑩ are slightly smaller ones, again with centromeres at their ⑪ centers; and there are the two very small ones. Now notice the two remaining chromosomes and how they differ between the male set at the left and the female set at the right. ⑫ There are the two identical ones in the female and the two ⑬ dissimilar ones in the male.

The first three pairs--the ones that are the same in ⑭ both males and females--are called "autosomes". The others ⑮ are called "sex chromosomes". In the fly, the smaller ⑯ chromosomes are called "X chromosomes". Thus the female is said to have an XX karyotype. The extra, different ⑰ chromosome in the male is called a "Y chromosome", and the male is said to have an XY karyotype.

⑱ Here are the chromosomes of a grasshopper. In this case the female has 11 pairs, while the male has 10 pairs and only one copy of the 11th type of chromosome. That ⑲ last type of chromosome again is called X. The female ⑳ karyotype is XX and the male karyotype is XO or X-. It is just as if the grasshopper reduced the Y chromosome to invisibility. Otherwise it has the same system of sex determination as the fly.

This same system works for most animals; the female has two X chromosomes, and the male has one X and one Y chromosome. However, there are a few groups of animals that modify this system. Moths, butterflies, birds, and amphibians are designed such that males have the two

identical chromosomes, and females have one of those
㉑ chromosomes and one extra, different chromosome or one
of those chromosomes and no extra chromosome. In
these cases, the karyotypes are named differently. That is,
the males are said to have ZZ karyotypes, and the females
have WZ (Z-) karyotypes. But notice that there is little
difference between this situation and the XY (X-) situation.
The only reason to use different letters is to call attention
to the fact that the males, rather than the females,
have the two identical sex chromosomes.

㉒ Finally, here are the chromosomes of humans. This
seems more complex, because there are more chromosomes than
in the other situations we have seen, but it turns out to be
similar if you identify all the chromosome pairs. There are
㉓ 22 pairs of autosomes and one pair of sex chromosomes. This
set is from a male--there is one large X and one small Y
㉔ chromosome. The next set shows the chromosomes of a female--
there are the same 22 autosome pairs and then two X chromosomes.
You can see that human and fly sex chromosomes follow
the same pattern, except for the relative sizes of the X
and the Y chromosomes.

This general pattern: one pair of sex chromosome; two different types; one sex with two of the same type; one sex with one of each type: this pattern holds true for most animals and some plants that have male and female individuals, also. It is clear that here is a general cytological feature, a chromosome, connected with the sex of an organism. Maybe we are even seeing a fundamental determinant of an individual's sex.

What about the two different sex chromosomes, the X
and Y chromosomes--they are not identical, clearly. Are
㉕ they really an "homologous" pair? In one way they are.
When the two chromosomes occur in the same cell (like in
the XY cells of male fruit flies), and when this cell undergoes
meiotic division (like in the formation of fruit fly
sperm), then the two chromosomes are separated by the first
meiotic division, just as are the other homologous pairs

of chromosomes. This means that gametes from a male fruit fly receive either an X chromosome or a Y chromosome.

㉖ In females, of course, the two X chromosomes are homologous: they separate during meiosis. All the gametes formed have either one or the other of them.

If you think about it, this situation explains why a
mating of flies produces approximately 50% male and 50%
㉗ female progeny. You have to consider the following facts:
a mating is always arranged between a male and a female;
㉘ half the male's gametes carry an X chromosome and half
㉙ carry a Y chromosome; all the female's gametes carry an
X chromosome. When you consider the combinations of male
㉚ and female gametes that can occur, using a diagram similar
to the one we use for genes and alleles, it is clear that
50% of the combinations will by XY (will receive an X from
the mother and a Y from the father) and 50% of the combinations
will be XX (will receive an X from the mother and an X from
the father). The XY combinations will turn out to be males;
the XX combinations, females. Thus: 50% males and 50%
females.

㉛ The same explanation works for humans. In this case a single mating usually does not produce enough off spring to give a good 50-50 ratio of males to females. The numbers are small, so chance fluctuation plays a larger part. It is not surprising to find that a single baby is either all male or all female and not 50-50. It is also not surprising that two or three babies--fraternal twins or triplets--might turn out to be all boys or all girls. Each combination of male and female gametes is a random event and is not influenced by other combinations, so it is easy to see how two or three XX or XY combinations could occur during the same mating. But overall, if we consider a large number of matings together, if we consider a large number of combinations of male and female gametes, the results should work out the same as with flies. This is because again half the male gametes carry an X chromosome and half carry a Y chromosome, so on the average half the combinations will be XX and half will be XY. Therefore of a large group of babies, half will be girls and half will be boys. If we must consider only a single mating--and most of us think that way--we express the situation in terms of probabilities: the probability that any given child will be male is 50%; the probability that it will be female is 50%.

Sex chromosomes also can explain some genetic experiments that otherwise would appear to violate Mendelian
(32) principles. There is one particular principle that is
especially vulnerable. Remember that Mendel, working with traits of pea plants, found that hybridizations gave identical results, no matter which parent--male or female--contributed the dominant or recessive allele. That is, in the jargon of geneticists, reciprocal matings give the same results.

(33) Now watch this experiment, performed by Thomas Hunt Morgan in 1910. Morgan was working with fruit flies, Drosophila melanogaster. Fruit flies normally have red eyes. Morgan had found a mutant fruit fly that had white eyes. In the language that we developed in the first heredity module, eye color is a trait controlled by one (or more) genes. White eyes are the result of a mutant allele of one gene for eye color; this allele is called w. Red eyes are the result of the normal (wild-type) allele, called w^+. Without further information, without knowing the phenotype of the w^+w heterozygote, of course, we cannot tell whether w or w^+ is the dominant allele.

(34) This was Morgan's first cross: a white-eyed male with a red-eyed female. The result: all progeny were red-eyed. This is what we would expect if w^+ were the dominant allele. Next Morgan mated the progeny red-eyed males and females. Assuming everything goes okay, we would expect 3/4 red-eyed, 1/4 white-eyed progeny. This also was true. But
(36) notice something strange: all the white-eyed progeny of
this second mating were male.

㊲ Morgan tried another cross: this time a white-eyed female with a red-eyed male. This is the reciprocal of the first cross, and normally we would expect the same results: all red-eyed progeny. But instead, we see that all the males were white-eyed and all the females were red-eyed.

It is clear that this trait, eye color, significantly departs from Mendel's principles and that the departure has something to do with sex. The results of the mating experiments depend on the sex of the parents and on the sex of the progeny. The trait seems somehow associated ㊳ with sex and therefore is called "sex linked".

How can we explain these strange results? Remember that I said before that the sex chromosomes can help with ㊴ the explanation. All we have to do is assume that the gene for eye color, w, is attached to or carried by the flies' X chromosome and the X chromosome only--there are no copies of the gene on the Y chromosome.

㊵ What does this mean? In females, with two X chromosomes, the genotypes and phenotypes are just what you would expect. The w^+ allele is dominant, so w^+w^+ flies and w^+w flies would have red eyes and ww flies would have white eyes. ㊶ In males, however, there would be only one copy of the gene, the copy on the one X chromosome. In this case, the one allele present would determine what you would see. A fly with a w^+Y genotype would have red eyes, and a fly with a wY genotype would have white eyes. (Notice that I wrote the "Y" just as a marker. It tells you that the allele it is with is on the X chromosome, and that the Y chromosome is present without carrying another allele of the same gene. I do not write the "X", because I do not think it is needed.)

Now let's see how this explains the results of Morgan's crosses. When I say "explains", what I am after is assigning appropriate and consistent genotypes to the phenotypes we see.

㊷ In the first cross--a white-eyed male with a red-eyed
㊸ female--we can assign the genotypes wY to the male and
w^+w^+ to the female. Notice that we assume here that the
female is true-breeding for red eye. We don't really know
this--after all, w^+w is also red-eyed. But let's accept
it as a reasonable assumption now, and later if you wish
㊹ you can see if the w^+w would work. From the wY male, two
forms of gametes are produced: those carrying the X chromosome with the w allele and those carrying the Y chromosome.
㊺ From the w^+w^+ female, all the gametes carry the X chromosome
㊻ with the w^+ allele. The combinations formed are w^+Y--red-eyed
males-- and w^+w--heterozygous red-eyed females. All the
flies are red-eyed, and this matches the results actually
observed.

㊼ In the next cross, when these w^+Y and w^+w progeny are
㊽ mated, the male produces gametes carrying w^+ X chromosomes
㊾ and gametes with Y chromosomes. The female produces gametes
with w X chromosomes and gametes with w^+ X chromosomes.
㊿ There are four combinations after fertilization: females
with w^+w^+ genotypes and with w^+w genotypes, and males with
w^+Y genotypes. and with wY genotypes. All the females have
red eyes, half the males have red eyes, and half the males
have white eyes. Or put another way, one fourth of the
progeny are males with white eyes. This again was what
was actually observed.

(51) There is one more cross--the white-eyed female with
(52) a red-eyed male. We can assign genotypes without trouble.
The females must be ww, w alleles on both X chromosomes.
The males must be w^+Y, a w^+ (red) allele on the one X
chromosome.

(53) The gametes from the females all will carry one X
chromosome with a w allele. The gametes from the male
will either carry an X chromosome with a w^+ alleles, or
will carry a Y chromosome. When male and female gametes
are combined, the results will include w^+w females--
heterozygous red-eyed females--and wY males--white-eyed
males. Once more the gametes predicted by this system

of placing alleles only on the X chromosome correctly reflect what actually is observed.

Since Morgan's first experiments with white-eyed mutants of Drosophila, many other genes have been found in flies, humans, and other species that are sex-linked and are distributed in mating experiments as if they were (54) located on one particular sex chromosome. Most sex-linked genes in both flies and humans turn out to be on the X chromosome. No one knows why this is true--it just seems to work out that way. A few genes have been found to be on the Y chromosome, though, so this too is possible. In this case the pattern of heredity is of course different. (55) A trait linked to the Y chromosome can only be found in males.

I have some problems now to help you solidify your understanding of the concept of sex linkage. There are two things in particular that I want you to be able to do. First, identify whether a trait is sex-linked from mating data, second, explain mating data on sex-linked traits by making hypotheses on the location of genes and whether alleles are dominant or recessive. Okay, here are the first three problems. What you will see is data on or descriptions of the heredity of a particular trait: (56) turn off the tape and try to decide whether the trait is sex-linked. When you have decided, or if you cannot decide, turn the tape back on and listen for the answer.

(57) Here is the first problem: A male Drosophila with normal sized wings mates with a miniature-winged female. The progeny were: 75 males with miniature wings and 68 females with normal wings. What do you think? Is the gene for wing size sex- linked? Turn off the tape if you need time to think.

Okay. This is a clear case of sex linkage, because the distribution of wing type depends absolutely on the sex of the progeny: males have miniature wings, and females have normal wings. You don't need anymore information to decide that the "m" gene for wing shape is sex linked.

(58) Next problem. A male fly with a black body was mated with a normal (yellow and black striped) female. The progeny were 26 black males; 23 normal males; 27 black females; and 28 normal females. Turn off the tape and decide.

There is something strange about this mating--maybe you recognize it. To get results like this, one of the parents had to be heterozygous. It would be the parent that has the dominant phenotype, whichever one that is--it turns out to be the normal female. Notice, however, are the same for the male and the female progeny. Does this mean that the black body gene is not sex-linked. Not necessarily! It is possible to get these results, even if the trait were sex-linked.

(5 In order to tell which is the correct scheme, you must ask for information on the reciprocal cross, in this case a normal male with a black female. If the results are the same--no difference between male and female progeny--this is strong evidence that the gene is not sex linked. If the results are different, the gene is probably sex linked.

It turns out that this gene, the gene for black body, is located on an autosome and therefore is not sex linked.

(60) Third, a bar-eyed female Drosophila mates with a bar-eyed male. The result is: 20 normal males, 22 bar-eyed males, and 50 bar-eyed females. Is the bar-eyed trait sex linked?

Again, this cross is kind of strange--the parents both have the same phenotype, yet the progeny differ. Just as in the last problem, the parents must be heterozygous, hiding normal genes in their genotypes somewhere. The important thing, though, is that the distribution of the trait in the progeny differs between the males and the females. The males segregate into bar-eye and normal types, while the females are all bar-eyed. Therefore the gene for bar-eye must be sex-linked.

(61) Now, before trying any more of these problems, I want you to "explain" these first three. By "explain" I mean you should assign genotypes to the parents, genotypes that will fit the phenotypes of the parents and will recombine to give genotypes that fit the phenotypes of the progeny. Assigning genotypes includes deciding whether the gene is sex-linked, which allele of the gene is dominant, whether the parents are homozygous or heterozygous, etc.

(62) Okay, with these things in mind let's go back to the mating of the normal male and the miniature-winged female. Assume that there is a gene called "m" with two alleles: the mutant "m" allele that gives miniature wings and the wild-type "m^+" that gives normal-sized wings. Try to assign the right genotypes to the parents. Go.

(63) Here is the answer. First, you know that the gene is sex-linked. A best guess is that the gene is on the X chromosome. Write in the Y chromosome for the male now. Second, the male must have an "m^+" allele to get a normal phenotype, since he has only one allele of this gene. Thus his genotype is m^+ Y. Third, the female parent must be m m genotype in order to give all male progeny. (If she had any m^+ alleles, they would show up in the males as m^+ Y genotypes.) These are the parental genotypes. But which allele is dominant? Well, note that the female progeny must be m^+ m, and since they are normal phenotype, the m^+ allele must be dominant.

(64) Second problem: the black-bodied male and the normal female. This was a problem where you couldn't tell whether the gene was or was not sex-linked. It turns out that there are both sex-linked and autosomal explanations for the data. Can you give them both? Turn off the tape and try.

(65) Here is the non-sex linked scheme. Note that the progeny distribute 50-50 with respect to body color. This occurs when a homozygous recessive mates with a heterozygote, so that is what I have diagrammed here. In this diagram I am assuming that the black trait is recessive and the wild-type is dominant. I don't have any evidence for that from the information given. I could just as well assume that the black trait was dominant, and worked out the problem with the male heterozygous and the female homozygous. However, it is often a good guess that the wild-type allele will be dominant. But not always!

(66) Here is the scheme assuming that the gene is sex-linked. Again, I use b for black allele, and b^+ for normal allele. This time I assume that the black gene is on the X chromosome. First, the male must have a Y chromosome; second, he must have a b-carrying X chromosome; so his genotype is bY. Third, the female must be heterozygous in order to produce two different kinds of males with two different phenotypes, so her genotype must be b^+b. Since her phenotype is normal, the b^+ allele would have to be dominant. In this case, assuming that the gene for black body is sex linked, the b^+ normal allele would have to be dominant.

As it turns out, the gene for black body is not sex linked. But the normal allele is indeed the dominant one.

(67) Third problem: the bar-eyed female and the bar-eyed male, who produce both normal and bar-eyed males, but only bar-eyed females. What are the parents' genotypes? Which allele is dominant?

(68) Here is the answer. Let's use B to denote the bar-eye allele and B^+ to mean the normal allele. First, you know the gene is sex linked, so put in the Y chromosome for the male; second, you know the male is bar-eyed, so put in the B allele. The male's genotype is BY. Third, you can see again that the female must be heterozygous in order to give

two different types of male progeny. Right? If she were homozygous bar-eyed, all the male progeny would have to be bar-eyed, but they weren't, so she isn't. Her genotype must be B^+B--heterozygous. Since her phenotype is bar-eye, the bar-eye allele must be dominant over the wild-type allele, an unusual but certainly possible situation.

(69) How about some similar problems with humans. There are a number of genetic conditions in humans that are sex linked--mostly detrimental, so they are usually called hereditary diseases. In 1971, there were about 70-75 sex-linked hereditary diseases known, each representing a gene on the X chromosome. These diseases include hemophilia, agammaglobulinemia (which leads to bacterial infection), gargoylism (in which a concentration of polysaccharides results in ugly folds of skin), two types of diabetes, albinism (leading to deafness), several types of mental retardation, and a curious condition in which the central incisors fail to develop.

Sex linked traits and genes in humans tend to appear in certain patterns. It is necessary to learn these patterns to tell whether a gene is sex linked, usually, because one seldom gets a chance to perform the controlled matings that one would use with flies or other animals. The patterns

(70) go like this. First, consider that most of the deleterious alleles will be recessive. In this case, the traits will occur much more often in males than in females. Females will carry the allele, but usually in the presence of a wild-type allele, so they will seldom express the trait. On the other hand, males will never carry the allele without expressing it. Males can pass the allele to their daughters, but never to their sons. But apparently normal "carrier" mothers can give the trait to their sons. Those are among the things you see with sex-linked recessive alleles. You might work out the characteristics of sex linked dominant alleles yourself.

(71) The most famous example of a sex linked recessive "disease" allele was the allele for hemophilia that arose in Queen Victoria. She had lots of children and passed the allele to three of the royal families of Europe

Among a sample of 100,000 humans observed over a ten-
(72) year period, there were 100 cases of muscular dystrophy. Over eighty of these were in boys. Is muscular dystrophy sex linked?....It is indeed. How about the few girls with muscular dystrophy? It turns out that there is more than one gene involved in this disease, and it is possible to acquire it from a mutation in a gene on an autosome. Almost undoubtedly, the girls have this type of dystrophy.

(73) In 50 marriages between men who have red-green color blindness and women who are not color blind, one-fourth of the children are color blind. Equal numbers of the color blind children are boys and girls. In 50 marriages between non-color-blind men and color-blind women, half the children are color-blind boys and half are normal girls. Is this trait sex linked?....Again, yes, it is. The giveaway is that the results for reciprocal matings are not the same—the results depend on the sex of the parents. Can you tell whether the allele for color-blindness is dominant or recessive?

(74) One final problem. Several families are known in which all the males have hairy ears. None of the women in the family show this trait. Can you suggest a genetic explanation for this situation?

This trait certainly appears sex linked, but it is not inherited through the females as a recessive allele on the X chromosome. If it were a dominant allele on the X chromosome, it should show up in lots of the girls. One good explanation could be that it is an allele on the Y chromosome. Y chromosomes are always passed from father to son and never appear in girls. That fits the distribution of this trait.

Before we leave this topic, I should mention a limita-
(75) tion. There are some traits that vary with respect to sex, yet are controlled by autosomal genes. Baldness in humans is one of these. Another is the possession of horns in
(76) sheep. In sheep, a male heterozygous for the horned gene

has horns, while a female heterozygote is hornless. These traits are called "sex limited" rather than sex linked. The expression of the genes for these traits is apparently affected by the supply of sex hormone in the animals. The proper mating experiments are necessary to identify a given trait as sex limited or sex linked.

The determination of sex is an interesting problem in itself, but the discovery of sex chromosomes had even a more basic significance. It turned out to provide the first evidence on a question that was uppermost in the minds of the geneticists of the early 1900s. The question (77) was this: where in the cell are the genes located? And what do they look like?

You see, when Mendel first introduced the concept of the gene in 1865, microscopy was still rudimentary. People had little idea of the complexity of subcellular structure, so it was difficult for them to think of "genetic particles". Probably, this is one of the reasons they failed to accept Mendel's concept of a particulate gene.

But when DeVries and Correns reintroduced the concept of the gene in 1900, microscopes had been greatly improved. Various cells in very many species had been described. Flemming had even described mitosis in animal cells in the 1800s, others had described meiosis and fertilization and their effect on the numbers of chromosomes in the cell. All this experience with subcellular structure colored the response of the biologists that heard DeVries and Correns. The words, "particulate gene", stimulated not disbelief but excitement. "Which of the particles that we have been watching represents the gene and therefore is responsible for directing the development of the cell and of the whole organism?" Several investigators had already suggested a key role for the nucleus.

The American cytologist, W. H. Sutton, was first to formally associate genes with chromosomes. Proof of this proposition was not easy to obtain immediately. However the discovery of sex chromosomes associated with sexual characteristics did support the idea. I hope this module (78) has given you an idea of how sex linkage supports the idea of genes being on chromosomes.

MODULEs 287 & 288

Module #287-88 Environmental Education as a Teaching and Learning Tool

This mod will provide ideas/methods/techniques to teach environmental education in an active learning format.

Lab Fee: $12 (includes 4 meals, lodging, and transportation)

Objectives:

1. The student will gain an understanding of a number of environmental education activities in which he, in turn, will be able to use in teaching students in a school setting.
2. Students will begin to understand the interrelationship of man and the environment through participation in the weekend experience.
3. Students will become familiar with published materials relating to various aspects of envioronmental education.
4. Students will observe and interact with alternative teaching styles demonstrated by the facilitators.

Instructional References and Materials:

1. 2 articles to be identified
2. Current elementary science texts
3. OBIS materials

Procedure: Module Overview: One weekend, students in ISMEP working on the environmental education module #_____, are taken to Land Between the Lakes: Youth Station for a day and a half of intensive exposure to a broad base of experiences relating to the environment and teaching. Students will view films, participate in discussions, simulations, and a variety of outdoor games and activities. Students and teachers are both actively involved in the whole weekend experience which comprises the substance of the module.

Student Activities:

1. Academic: Read articles in module before the weekend experience at LBL.
2. Time: Students are asked to meet in the Business Building parking lot at 3:30 PM on the Friday of the scheduled weekend. (Consult instructor for dates.) Students can expect to be back on the MSU Campus at 7:00 PM on Saturday.

3. Transportation:	MSU vans will transport students to and from LBL. Vans will depart from and return to the Business Building parking lot.
4. Dress:	Much of the time during the weekend will be spent outside. Take this factor and the weather into consideration when packing the following items:

Things to Bring

Extra change of clothing
Comfortable footwear
Towel and other personal items
Jacket or sweater
Raincoat/poncho

Things Provided by LBL

Sheets
Pillows
Blankets
Meals

Evaluation: Students are evaluated on their active involvement in the scheduled activities during the weekend.

MOD 289 **Batteries and Bulbs II**
Communicating, predicting

PREREQUISITE: MOD 176, **"Batteries and Bulbs I"**

OBJECTIVES:

1. Given an electrical diagram, you will be able to interpret the symbols and explain how the circuit works.
2. You will be able to explain thoroughly the difference between a series circuit and a parallel circuit and how each operates.
3. Given an electrical diagram, you will be able to construct the electrical circuit from the parts contained in the MOD tray.

INSTRUCTIONAL REFERENCES & MATERIALS:

1. ESS, Teacher's Guide for Batteries and Bulbs
2. ESS, Batteries and Bulbs II
3. Winter, The Physical Sciences, "Circuits," pp. 218-219; Dull, Metcalf, Williams, Modern Physics, pp. 412, 422, 423, and 424.
4. Clips, bulbs, batteries, switches, wire
5. Voltmeter

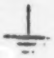
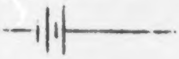
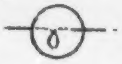
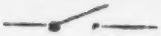
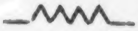
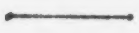
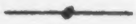
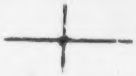
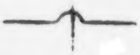
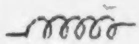
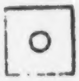
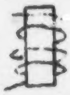
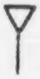
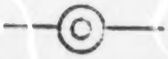
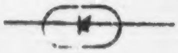
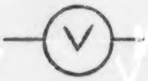
FINAL ASSESSMENT:

1. See objectives above.
2. See instructor for final assessment sheet in which you will construct a circuit from the materials in the MOD tray according to a given schematic diagram.

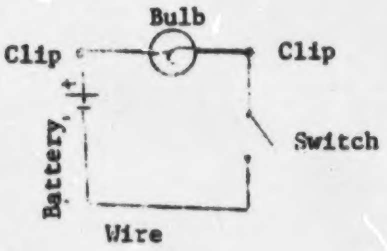
PROCEDURE:

1. Symbols and Circuits

In working with electrical circuits, it is very burdensome to make a complete drawing on paper. So, a code language has been designed using symbols. These symbols are standardized for all types of electric circuits. Become familiar with these basic symbols. A design using these symbols is called a schematic diagram.

Ground 	Battery 	Bulb 	Switch 
Resistance (Load) 	Wire 	Clip 	Wires Joined 
Wires Crossed but not joined 	Coil 	Magnet 	Electro-magnet 
Radio Antenna 	Earphone 	Diode 	Voltmeter 

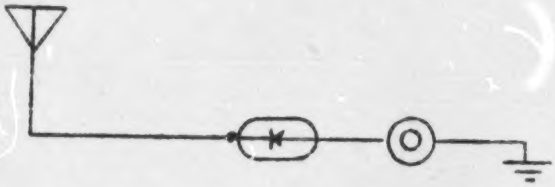
This diagram is a simple electric circuit drawn with symbols. Set up this circuit with actual materials. Explain what happens when the switch is closed.



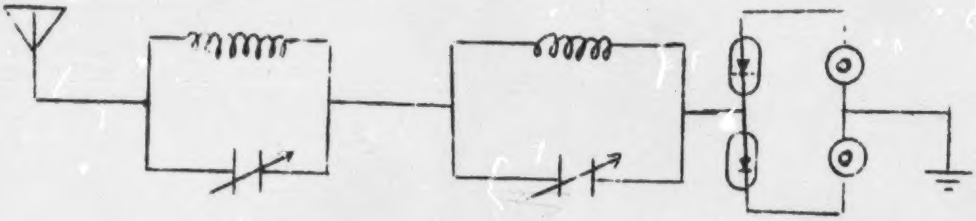
Turn the battery around. Now what happens?

Is there a difference in the intensity of the light bulb?

Can you read this schematic diagram of a simple radio?



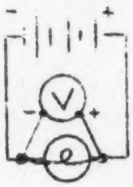
This schematic diagram shows a combination of two simple radios.



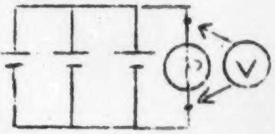
Take 3 batteries, 3 bulbs, wire, and 2 switches to set up an electrical circuit. Draw a schematic diagram to show how you wired your circuit. Be ready to explain this circuit to the instructor.

2. In this activity, you will use a voltmeter. There is a definite way to wire the meter into the electric circuit. The top of the battery is called the positive pole (anode) and the bottom is called the negative pole (cathode). When the voltmeter is entered into the circuit, always keep the positive (+) side of the meter connected to the positive side of the battery. You will be measuring the voltage load across the bulb each time. The voltmeter should not be connected permanently into the circuit. Wire the circuit, and then touch the leads of the voltmeter to each terminal of the bulb. The needle should move the meter up, not down. If the needle goes down, disconnect the meter immediately and reverse the leads. The meter must be in the circuit parallel to what you are measuring.

A. Set up this circuit. Measure the voltage on the bulb. _____v. Remove one battery from the circuit. Measure the voltage on the bulb. _____v. Now remove another battery. Measure: _____v. These batteries were set up in a series. Make a statement about this type of circuit.

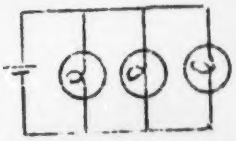


B. Set up this circuit. Measure the voltage on the bulb. _____v. Remove one battery. Measure: _____v. Remove another battery. Measure: _____v. These batteries were set up in a parallel circuit. Make a statement about this type of arrangement.



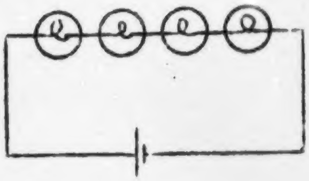
C. Now change the circuit slightly. Set up this arrangement. Measure the voltage across each bulb.
a. _____v.
b. _____v.
c. _____v.

Remove one bulb from the circuit. Does the voltage increase, decrease, or stay the same? __________ Remove another bulb. Does the voltage change now? __________ The bulbs are set up in a parallel circuit. Make a statement concerning the bulbs in a parallel circuit.

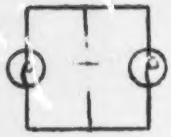


D. Set this up. Measure the voltage across each bulb.
1. _____v. 2. _____v.
3. _____v. 4. _____v.

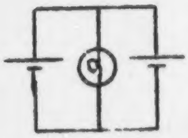
Remove one bulb at a time and measure the remaining ones. Make a statement about bulbs in a series circuit.

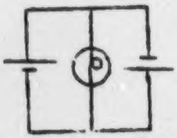


E. Set up this circuit. Notice the brightness of each bulb. Measure the voltage at each bulb. 1. _____v. 2. _____v. Remove one bulb from the circuit. Now what is the voltage across the remaining bulb? _____v.



F. Set up this circuit. Measure the voltage across the bulb. _____v. Remove one battery from the circuit. Does the voltage decrease? ________ Turn one battery around to form this circuit:





What is your observation?

Give an explanation.

MOD 290 Number Theory Revisited

The purpose of this MOD is to increase your confidence and your competence in number theory topics.

OBJECTIVES:

At the conclusion of this MOD you will be able to:
1. Use the tests for numbers being divisible by 2, 3, 4, 5, 6, 7, 8, 9, and 11.
2. Find the prime numbers by the sieve method.
3. Factor the composite numbers into primes.
4. Find the g.c.d. and l.c.m. of given numbers.
5. Use modular arithmetic in checking basic operations.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Number Theory
2. Wheeler's Fundamental College Mathematics, Chapter 3
3. Worksheets
4. Elementary School Mathematics by George F. Green, Chapter 7

PROCEDURE:

1. Review Sections I and III in MMP, Number Theory.
2. Study Chapter III in Wheeler's Fundamental College Mathematics as needed to fill out the worksheets.
3. Complete the following worksheets individually. After completion you may check work with your partner.

FINAL ASSESSMENT:

1. Bring all worksheets to evaluation.
2. Be prepared to take a test on problems similar to the worksheet problems.

WORKSHEET

1. Write the rules for divisibility by 2, 3, 4, 5, 6, 7, 8, 9, and 11.

2:

3:

3:

5:

6:

7:

8:

9:

11:

2. WIthout actually dividing, test each of the following numbers for divisibility by 5.

a) 6944

b) 81,432

c) 1,941,070

d) 50,177

e) 1,254, 866

f) 162,122

3. Find the missing digits in order to produce the smallest number for which divisibility holds.

a) 9 | 24__

b) 11 | 18__2

c) 36 | __11__

d) 24 | __23__

4. Determine whether the following are true or false.

a) 15 | 345

b) 45 | 3780

c) 16 | 1432

d) 17 | 1581

e) 44 | 2772

f) 40 | 2640

5. Could Mr. Jones put the 2142 papers on his desk into six equal piles? Eighteen equal piles? Seven equal piles? Could he divide $6541.29 equally among nine employees?

6. Since 7 x 11 x 13 = 1001, to test whether a number is divisible by 7, 11, or 13, one may divide the number by 1001 and then test to see if the remainder is divisible by 7, 11, or 13. If the remainder is divisible by one of these, then so is the original number. Test this theory on the following numbers.

   a) 56,264

   b) 275,004

   c) 363,848

   d) 1,825,308

7. Write the following numbers as products of prime factors.

   a) 144

   b) 178

   c) 256

   d) 2000

   e) 108

   f) 299

8. Apply the "sieve of Eratosthenes" to get all primes less than 150.

9. Find the greatest common divisor for each pair of numbers.

   a) 105 and 30

   b) 72 and 54

   c) 46 and 38

   d) 188 and 72

   e) 84 and 288

10. Find the least common multiple of the following.

a) 8 and 20

b) 56 and 21

c) 42 and 66

d) 22 and 90

e) 252 and 96

11. Label each of the following as true or false.

a) $6 \times 5 \equiv 4(\text{mod } 6)$

b) $18 - 5 \equiv 1(\text{mod } 12)$

c) $7 + 4 \equiv 5(\text{mod } 6)$

d) $6 \equiv 3(\text{mod } 8)$

f) $34 \equiv 7(\text{mod } 13)$

12. Construct addition and multiplication tables for a five-minute clock.

13. By inspection, find the smallest whole number x that will make each of the following statements true.

a) $x \equiv 5(\text{mod } 3)$

b) $x + 10 \equiv 9(\text{mod } 4)$

c) $x + 4 \equiv 6(\text{mod } 7)$

d) $x + 5 \equiv 7(\text{mod } 5)$

14. Perform the following operations and check by casting out 9's and 11's.

a) 583 + 427

b) 583 x 427

c) 385 - 156

MOD 291 Problem Solving Extended

This MOD is intended to provide an extended experience and more precise understanding of problem solving.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. Organize approaches to solve problems.
2. Understand ways problem solving would reinforce the study of standard topics in the elementary mathematics curriculum.
3. Understand students' wrong approaches to problem solving.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Number Theory
2. Grossnickle, Brueckner, and Reckzeh: Discovering Meanings in Elementary School Mathematics , fifth edition

PROCEDURE:

1. In MMP, Number Theory, do Activity 8: Part A, 1; Part B, 1, 2, 3; Part C, 1 and 2; Part D, 1, 2, and 3. Do Activity 9: Part A, 1, 2, 3, 4, and 5; Part B, 1, 2, 3, and 4.
2. In Discovering Meanings in Elementary School Mathematics, read pp. 302-316.
3. Write answers to questions 2, 3, 4, 6, 7, 9, 10, and 12 on p. 316 in the text referred to in #2 above.

FINAL ASSESSMENT:

Be prepared to take a written test on activities and questions from part 2 of the procedures outlined above.

MOD 292 Operations on Rational Numbers

This MOD is designed to give you practice in operations on rational numbers.

OBJECTIVES:

After you have completed this MOD you will be able to:
1. Add and subtract fractions.
2. Rewrite mixed numbers as common fractions.
3. Multiply and divide fractions.
4. Combine operations with complex fractions.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Rational Numbers
2. Houghton-Mifflin Company fifth and sixth grade textbooks
3. Worksheets

PROCEDURE:

1. Review operations of subtraction, addition, multiplication, and division in MMP, Rational Numbers.
2. Survey material in elementary textbooks relative to operations on rational numbers.
3. Complete the following worksheets individually. Then check with your partner.
4. Prepare a game to reinforce some concept from above operations.

FINAL ASSESSMENT:

Be prepared to take a test on problems similar to what you have done in the worksheets.

WORKSHEET #1

Add:

1. 2/3 + 3/4

2. 7/12 + 2/15

3. 3/5 + 1/5

4. 2/3 + 7/3

5. 1/7 + 3/14

6. 2/5 + 2/15

7. 2/3 + 3/5

8. 8/5 + 4/7

9. 1/5 + 2/3 + 4/15

10. 1/3 + 3/7 + 6/21

11. 3/[illegible] + 1/8 + 7/12

12. 2/5 + 7/10 + 1/15

13. 3/7 + 1/6 + 2/15

14. 2/11 + 1/3 + 4/5

15. 5/14 + 3/35 + 7/10

WORKSHEET #2

Subtract:

1. 7/9 - 2/9
2. 3/5 - 1/2
3. 2/5 - 1/3
4. 2/5 - 4/5 + 3/5
5. 1/6 - 5/12
6. 3/5 - 4/15
7. 2/7 - 4/3
8. 7/2 - 4/5
9. 3/4 + 5/8 - 1/32
10. 2/3 - 11/7 + 1/21
11. 3/5 - 9/10 + 4/15
12. 1/4 - 5/8 + 11/12
13. 3/2 + 1/6 - 7/18
14. 5/3 + 2/9 - 7/27
15. 11/36 - 5/42

WORKSHEET #3

Multiply:

1. 2/3 x 4/5
2. 2/3 x 5/7
3. 2/3 x 6/7
4. 4/7 x 1/3
5. 5/8 x 2/9
6. 7/13 x -5/9
7. -21/17 x 13/6
8. -4/5 x -3/2
9. -2/7 x 6/-5
10. -3/5 x 11/4
11. -2/5 x 2/5 x -1/5
12. -4/3 x 4/3 x 1/3
13. 16/3 x -5/8
14. 246/54 x 36/16
15. 25/14 x 7/10

WORKSHEET #4

1. $7/8 \div 3/5$

2. $2/3 \div 7/5$

3. $\frac{5/8}{2/3}$

4. $\frac{3/7}{2}$

5. $3/4 \div -7/8$

6. $\frac{-3/7}{11/12}$

7. $-3/8 \div -9/5$

8. $\frac{4}{2/5}$

9. $-8 \div 2/3$

10. $-5/3 \div 15/4$

11. $3/8 \div -9/5$

12. $16/-3 \div 4/-3$

13. $-10/7 \div 5/-14$

14. $25/12 \div -15/24$

15. $\frac{-3/5}{-8/15}$

WORKSHEET #5

Simplify:

1. $\dfrac{1 - 1/3}{2 + 2/3}$

2. $\dfrac{2/3}{2 - 2/3}$

3. $\dfrac{1 + 1/6}{1 - 1/3}$

4. $\dfrac{3 + 1/5}{2 - 3/5}$

5. $\dfrac{3 + 3/5}{5 - 1/2}$

6. $1 + \dfrac{1}{1 + 1/2}$

7. $1 - \dfrac{1}{1 - 1/2}$

8. $3 - \dfrac{2}{1 - 1/3}$

9. $2 - \dfrac{5}{1 - 2/7}$

10. $3 - \dfrac{2}{1 - 1/7}$

MOD 293 Transformational Geometry III

This MOD is designed to give a limited introduction to projective and topological transformations.

OBJECTIVES:

At the conclusion of this MOD you will be able to:

1. List some invariants of projective transformations and give everyday examples of the implications of these invariants.
2. Describe clearly the relationship between the concept of similarity, proportions involving ratios of corresponding sides, and shadows of objects cast by a point light source.
3. List some topological invariants and give an everyday implication of each.
4. Outline some activities for first- or second-graders to help them grasp important topological invariants.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. MMP, Transformational Geometry
2. Penlight, sunlight, or slide projector, cut-out shapes, balloons, rubber sheet or "stretchy" material, clay, dough, or some material that can be molded, construction paper, ruler, scissors, scotch tape, protractor, string
3. Current elementary mathematics textbook series

PROCEDURES:

In MMP, Transformational Geometry, do:

1. Activity 9: 1 and 2
2. Activity 10: Part I-A (1, 2, 3, 4),
   I-B and I-C,
   Part II--1, 2, 3, 4, 5, and 6
3. Activity 11: 1, 2, 3, 4, 5, and 6
4. Activity 12: 1, 2, 3, 4, 5, and 6
5. Activity 13: 1, 2, 3, 4, and 5

FINAL ASSESSMENT:

Be prepared to answer questions relating to the objectives.

MOD 294 Analyzing Elementary School Books

The purpose of this MOD is to allow you an opportunity to become familiar with and to analyze some current elementary science textbook series which are being used by some school systems.

OBJECTIVES:

At the end of this MOD you will present a study of three elementary science textbook series which will reflect relative emphasis on content areas, processes, and amount and type of activities contained in the series.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Gega, Science in Elementary Education, 2nd ed., pp. 14-18
2. Kuslan and Stone, Teaching Children Science, 2nd ed., pp. 158-165
3. Elementary science textbook series in the Resource Center

INSTRUCTIONS:

Select three elementary science textbook series found in the Resource Center. Review the textbooks and decide on an appropriate way to present in writing a comparison of the three series in terms of scope and sequence of science content areas, scientific processes, and the amount and type of activities offered. Offer suggestions as to how to best use the textbooks.

FINAL ASSESSMENT:

1. Submit your prepared report to an instructor in good form.
2. After the instructor has read your report, schedule a conference with the instructor to discuss your report.

MOD 295 Communicating through Graphs and the Written Word

COMMUNICATING

"(SAPA) development in this category begins with bar graph descriptions of simple phenomena, and proceeds through describing (in written or spoken words) a variety of physical objects and systems, and the changes in them, to the construction of graphs and diagrams for observed results of experiments." SAPA, Purposes, Accomplishments, Expectations, p. 6.

OBJECTIVES:

1. Given a Fahrenheit and a Celsius thermometer, collect data and plot a graph for the relationship between readings on the thermometers of the temperature of water.
2. Given four tables of data, you will construct a graph for each using the information given in the table.
3. Given four graphs, you will interpret the graph and interpolate and/or extrapolate for the value requested.
4. Given the physical system described in this MOD on page 9, you will report in writing what you see happening in the small group activity to the system from "zero time."
5. You will observe carefully a phenomenon of your own choice appropriate for use in an elementary classroom and write a description of what happens. Select a phenomenon that will allow the use of a graph.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. SAPA 25, Introduction to Graphing
2. SAPA 38, Using Graphs
3. SAPA 44, Surveying Opinion
4. SAPA 48, The Bouncing Ball
5. This MOD, pp. 2-9
6. Graph paper
7. Vinegar, baking soda, moth balls
8. Two thermometers, one Celsius, one Fahrenheit

FINAL ASSESSMENT:

1. Construct a graph in the instructor's presence according to Objective 1.
2. Orally interpret a graph for the instructor according to Objective 2.
3. Present written reports fulfilling Objectives 1, 2, 3, 4, and 5.

ALL GRAPHS AND REPORTS MUST BE IN GOOD FORM.

PROCEDURE:

In a laboratory activity you are asked to graph the relationship between the Celsius and Fahrenheit temperature scales. Use two thermometers--one Celsius and one Fahrenheit. Take temperatures of water at different temperatures from the freezing point to the boiling point. Either the reading on the Celsius scale or the reading on the Fahrenheit scale may be considered as the manipulated variable. If the Celsius temperature is manipulated, it then determines the value of the Fahrenheit temperature.

Now, given a grid, how are you to label the axes and the divisions along these axes? If C is the manipulated variable, it is usually plotted in the horizontal direction; F, then, is plotted in the vertical direction. Given horizontal and vertical divisions, it might be well to leave space for values of the temperatures that are either below the freezing point of water or above its boiling point. Thus, the axes might be, although they do not necessarily have to be, labeled as shown in the graph, MOD 295, p. 5. You must consider the range of your data and the number of graph divisions in order to set up a value for each division. Then the data in the table you make may be plotted as shown. Note that the graphed line is the smooth--straight or curved--line that best fits the plotted points, so that displacements of points above the line equal displacements of points below the line. The points determined from laboratory data may not lie exactly on the graph that is finally drawn; therefore, the graph is a close approximation to the facts.

After you have prepared your graph, compare it with the one on page 5.

To be consistent with SAPA instruction, the following checklist of graphing conventions is adapted from SAPA, Guide for Inservice Instruction, p. 123. In interpreting your graphs you will be expected to use these conventions.

1. The manipulated variable is graphed on the horizontal or x-axis.
2. The responding variable is graphed on the vertical or y-axis.
3. Each axis is labeled so as to describe what was observed.
4. The intersection of the x-axis with the y-axis is the zero or starting point of the x and y number lines.
5. The units of measurement of each pair of observations are indicated along with the labels on the x-axis and y-axis.
6. Numerals are placed along each axis in regular intervals as on a number line.
7. The graph is constructed on a grid formed by horizontal and vertical lines, each line having an assigned value as shown by the numerals along the x-axis and y-axis.
8. Numerals along each axis are placed on the vertical and horizontal lines of the grid.
9. The numeral on the y-axis where a horizontal line crosses the y-axis determines the y-coordinate of any point on the horizontal line.
10. The numeral on the x-axis where a vertical line crosses the x-axis determines the x-coordinate of any point on the vertical line.

Consider now the problem of graphing the relationship between Celsius and Fahrenheit temperatures. When C changes from 0 to 100, F changes from 32 to 212; therefore, 100 Centigrade degrees are equivalent to 180 Fahrenheit degrees or each Centigrade degree is equivalent to 1.8 Fahrenheit degrees. Thus, you might write $F = 1.8\ C$. However, this does not hold since F is not zero when C is zero. At a glance, you can see that the graphed line "starts" at $F = 32$ when $C = 0$. Therefore, a word sentence describing the relationship might read like this:

> The Fahrenheit temperature of a system is equal to thirty-two plus the quantity of one and eight-tenths times the Celsius temperature of that system.

The algebraic sentence of the number sentence describing the same relationship would be written like this:

$$F = 1.8C + 32$$

It is evident that the algebraic sentence is more concise.

You may use a graph in order to interpolate or extrapolate. For example, given a Celsius temperature of 110°, you may find the corresponding Fahrenheit temperature in the following way:

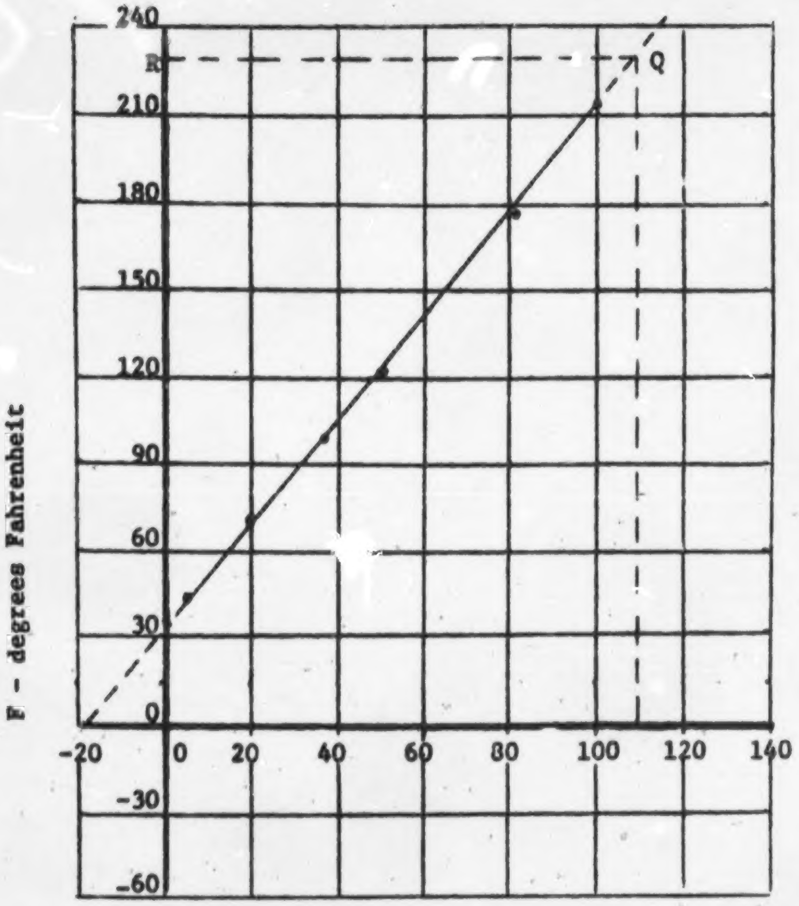
a) Trace the horizontal axis to 110°C.
b) Trace vertically upward until the graphed line is reached at Q.
c) Trace left horizontally from Q until the F axis is reached at R.
d) Read the desired value of F at R. F = 230°

Because the 110° is higher than any value of C plotted, the process is called extrapolation. The process would also be called extrapolation for values of C below 0°. In these cases the graph is extended at either end. If the steps above were followed for 72°C, the process would be called interpolation. In this case the value is found from the graph between the points initially plotted.

TITLE: A graph showing the relationship between Celsius and Fahrenheit **temperatures.**

or

A graph showing how Fahrenheit temperature varies with respect to Celsius temperature.



C - degrees Celsius

Draw a graph corresponding to each of the following tables of data. Remember to give the graph a title and to label the axes. If you wish, use graph paper provided in the laboratory. Recall that it may not be practical to draw a graph showing the point (0,0). In some cases, graphs are drawn in order to show trends rather than to show relationships to an absolute scale.

Table #1

Relationship between distance and time for a moving object

Distance (m)	Time (sec)
0	0
3	1
5	3
9	4
12	4.2
16	4.6
20	5.5

Table #2

World total population estimates according to U.N. "Low" variant

Year	Population
1960	2,998,180
1965	3,265,555
1970	3,544,781
1975	3,840,439
1980	4,147,337
1985	4,462,720
1990	4,782,859
1995	5,109,362
2000	5,448,533

Table #3

Relationship between weights of zinc and sulfur which combine to form zinc sulfide

Zinc (g)	Sulfur (g)
15.4	7.5
32.5	16.0
65.4	32.0
81.7	40.0
96.0	47.0
122.0	59.5
148.0	72.5

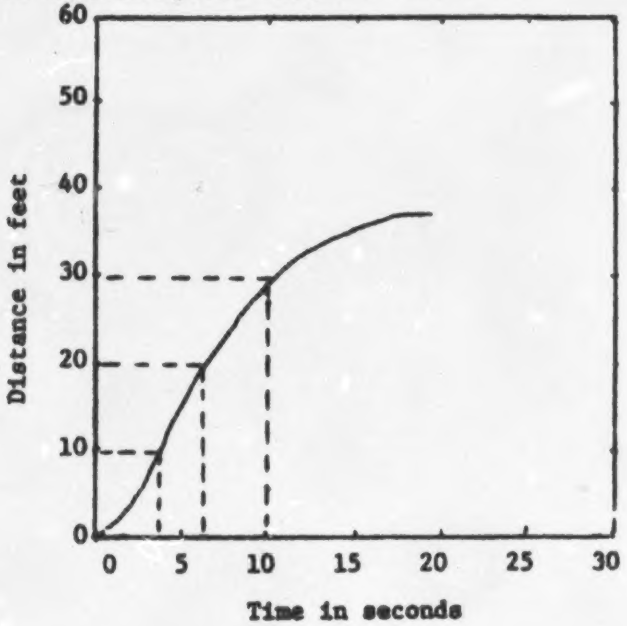
Table #4

Relationship between volume and Kelvin temperature of a gas at constant pressure

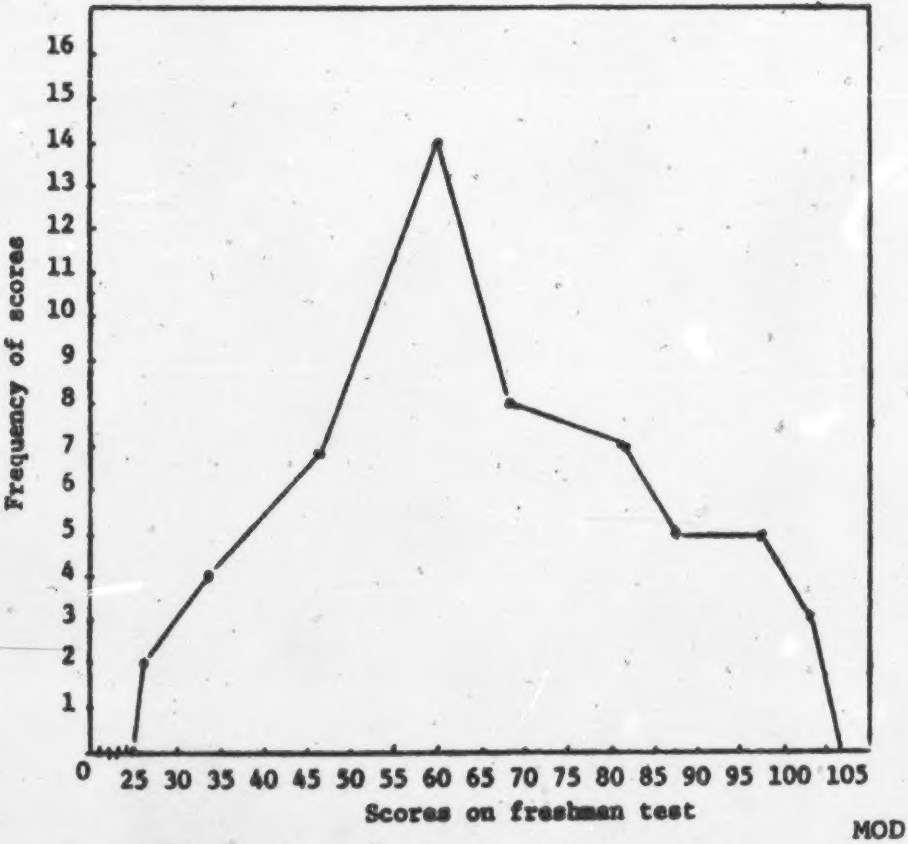
Volume (cc)	Temperature (^{o}K)
348	95
498	137
1000	273
1350	368
1540	420
2020	546

From your graphs predict from:
Graph 1, the time required for 14 m
Graph 2, population for the year 2025
Graph 3, sulfur needed for 200 g of zinc
Graph 4, temperature for 1200 cc of the gas

Non-uniform Speed, Distance Versus Time

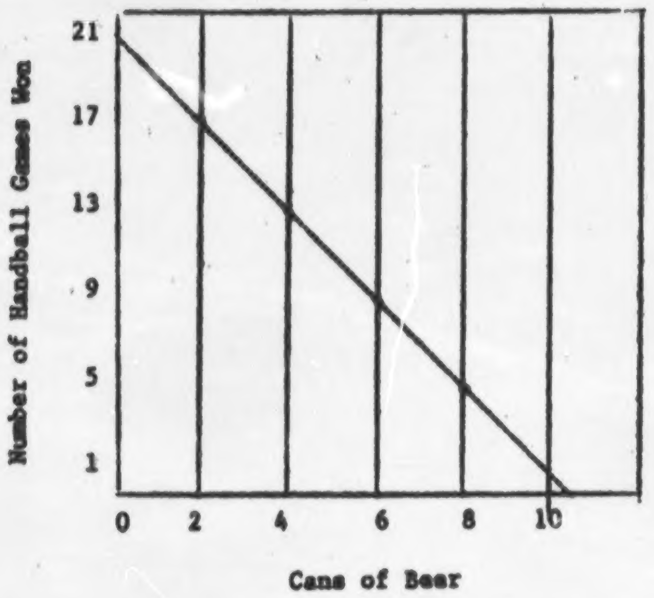


A Frequency Polygon of the Test Scores from 80 Freshman Students

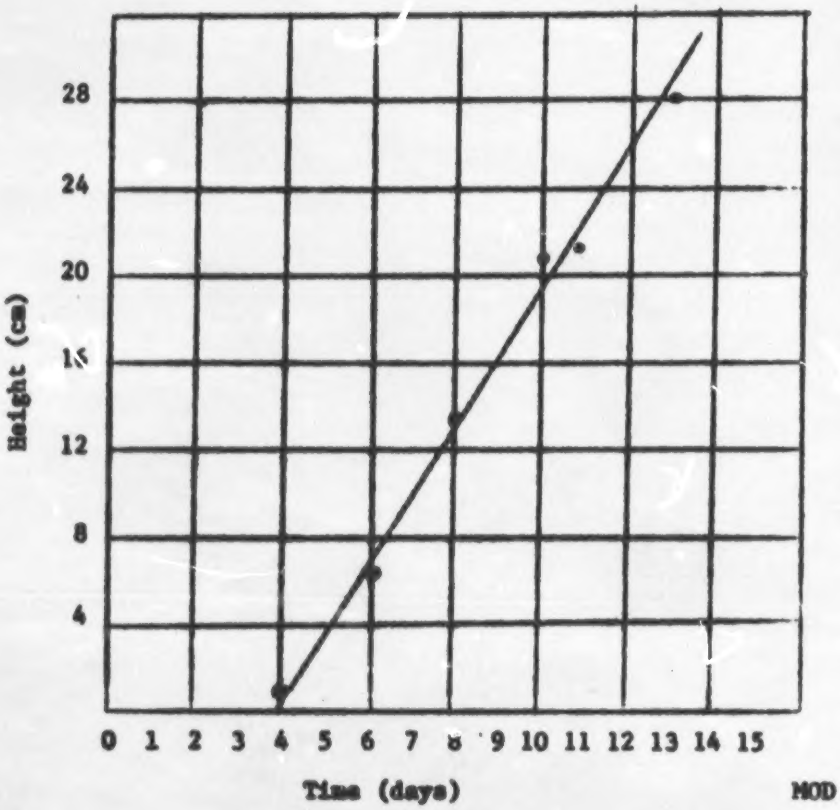


MOD 295

Number of Games Won Plotted against Cans of Beer Consumed



Height of Plant Plotted against Time of Growth



Physical system referred to in objective 3:
Work with a group of 4 or 5 students for this activity.

Fill a tall narrow container with three parts water to one part vinegar. Add enough baking soda to produce a lively reaction. After the reaction has subsided, drop two or three mothballs into the solution. Call this "zero time" and observe and carefully record your observations for twenty minutes so that you can write a complete report of what you see. Compare your written account with the accounts of others in your group. This activity sharpens your observations and gives you practice describing a phenomenon in writing. Sharing with your classmates should help you with both of these skills.

Remember to be as quantitative as possible.

MOD 296 **Soil Nematods**
Observing, classifying

OBJECTIVES:

1. **Given the soil ecology kit in the MOD tray, you will collect a sample of soil and process it for the purpose of extracting the soil nematods.**
2. **After obtaining a soil sample you will be able to use the apparatus provided to separate the soil nematods from the soil.**
3. **After separating the nematods from the soil sample, you will be able to concentrate them and fix them with an FAA solution.**
4. **After separating and fixing the nematods, you will examine them under the microscope to determine the number of kinds of nematods isolated.**
5. **After classifying the nematods in groups, you will be able to prepare drawings showing the distinguishing characteristic(s) of each group.**

INSTRUCTIONAL REFERENCES & MATERIALS:

1. **Soil ecology kit**
2. **Soil sample collected by the student**
3. General Information Section II, pp. 4-6 of this MOD
4. General zoology references on invertebrates
5. **General biology texts**
6. **FAA solution, general laboratory glassware, stereoscopic microscope**

FINAL ASSESSMENT:

See objectives above. Drawings of nematods should be made so that the individual diagrams are not smaller than 2 inches in length.

PROCEDURE:

General Information

Good soils generally are enriched with variable amounts of dead organic materials. The organic material or humus of soil imparts the deeper or black colors to soils and also increases the water-holding capacity of soil. In addition, organic material, as it is decomposed by soil organisms, adds basic inorganic substances to the soil. Soils that do not have a humus content are usually devoid of living organisms such as bacteria, fungi, protozoans, insects, worms, and nematods. Soils that have a humus content but no animal organisms are usually poor in nutrient content because of the stability of the humus content. In order that plants grow well on a natural soil, both humus and decomposer organisms are desirable components of the soil.

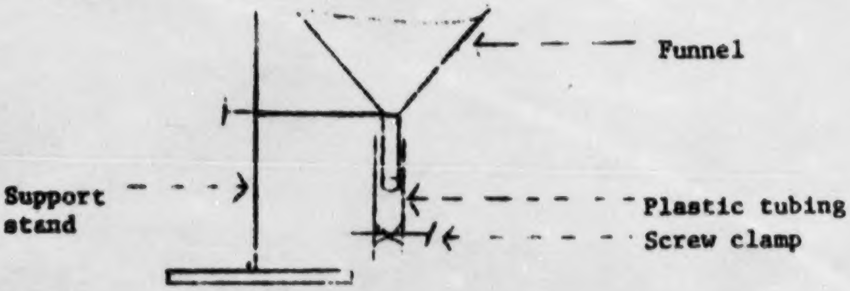
In this activity, you will be able to observe the large number of nematods present in the soil. You will also be able to show that several kinds of nematods are present.

Nematods are a group of organisms at the lower end of the scale of the animal hierarchy. By referring to pp. 4-6 and the taxonomic key found there, you will note that nematods are simple animals with a simple tube-within-tube construction and a false body cavity. The organisms possess both a mouth and an anus connected by a straight digestive tube. They usually feed by passing soil and its organic content through the digestive tube. The process of metabolism breaks down much of the organic content and frees some of the inorganic content which is then voided to the soil. Remember that plants need inorganic nutrients as a necessary requirement for growth.

Activities

1. Soil sample collection: Using the soil scoop provided, collect one jar of soil. The soil should be collected during the interval from late spring to early fall to insure the presence of nematods. The soil sample should be taken from a garden plot, flower bed, or near a stream bed to insure that it has an adequate moisture content. After removing the dry debris, or about ½ inch of top soil, press the soil scoop into the soil to the scoop's top rim. If the soil is moist enough, the sample will be retained in the scoop when it is retracted from the soil. Empty the soil from the scoop into a 16 oz. jar and take it to the laboratory.

2. Assemble the materials found in the MOD tray to form the apparatus shown below.



3. Pulverize the soil with your hands by crushing and breaking the larger pieces.

4. Using a portion of a nylon stocking, which you provide, make a bag to hold the soil sample.

5. Place the bag of soil into the funnel and add enough warm water to the funnel to cover the soil in the bag.

6. Allow the apparatus to stand in a warm room for 3 hours.

7. At the end of 3 hours, open the clamp on the plastic tubing and drain off about 5 ml. of the water in the funnel.

8. Pour the sample of water into a dish and examine the contents under the stereoscopic microscope.

9. If nematods are present, add 1 ml. of an FAA solution (formalin, acetic acid, alcohol) heated to 60°C. Mix the contents. After the nematods stop moving, pick them out of the solution with a fine pipette and place them along with some solution into a small screw-capped vial.

10. Repeat steps 7, 8, and 9 until you have collected several kinds of nematods.

11. Classify and draw the various kinds of nematods. Present to the instructor the collected nematods, along with your drawings.

General Information

The living kingdom of plants and animals is divided into four main categories on the basis of specific characteristics. These four categories, along with some of the distinguishing characteristics, are:

Group Monera:	Single-celled organisms having no definite nucleus in the cell. (bacteria and blue-green algae)
Group Protista:	Single and multicelled organisms lacking definite tissues or organ level structures. (algae, fungi, slime molds, and protozoa)
Group Metaphyta:	Multicellular plants. Living tissues and organ level structures (mosses, liverworts, ferns, conifers, and deciduous plants)
Group Metazoa:	Multicellular animals having tissues and organ level structures (all animals above the protozoan level)

In this MOD you will be concerned with animals in the Metozoa group only. The Monera, Protista, and Metaphyta are considered in MODs 202, 251, and 273.

Activities

The student will learn the following animal types by associating specimens placed in RB 243 with the names and descriptions given below.

NOTE: The animal kingdom is divided into two main groups: the invertebrates and the vertebrates. The invertebrates do not possess an internal skeleton. Invertebrates usually have an exoskeleton which is a hardened outside covering. Vertebrates have an internal skeleton or backbone supporting structure.

Main Group I - Invertebrates: Organisms having an exoskeleton, ventral solid nerve cord.

Common Name	
Sponges	Simple tubular organisms having a body wall made up of an outer protective layer (ectoderm) and an inner digestive layer (endoderm). Have spicules or protein fibers to strengthen the body wall. Have one opening into the digestive cavity serving as mouth and anus.
Hydroids, Jellyfish, Corals	Similar to sponges but having a special layer of tissue called a mesoglea between the outer and inner body wall layers. Have one opening into the digestive cavity serving as mouth and anus.
Flatworms	Similar to hydroids but are flattened dorso-ventrally to be flat organisms. Mesoglea developed into a true third body layer called a mesoderm. Mesoderm fills the space between the endoderm and ectoderm layers, therefore no body

	cavity. Have one opening into the digestive cavity serving as mouth and anus. (free living flatworms, tapeworms, and flukes)
Round Worms	Simple round tubular organisms having a hollow space or cavity between external body wall (ectoderm) and digestive tube. Mesoderm forming tissues as muscles, reproductive structures and excretory organs that lie between body wall and digestive tube. Have separate openings into digestive cavity serving as a mouth and an anus.
Segmented Worms	Elongate tubular worm-like organisms having a true body cavity between gut tube and body wall. Is called a true body cavity because it is lined with a special membrane. (earthworms and leeches)
Molluska	Organisms usually having calcareous inner or outer shells. Having a head, foot, and hump as body parts. (clams, snails, oysters, squids, and octopuses)
Arthropods	Organisms having well-developed jointed appendages
a. Crayfish, Lobsters, and Shrimp	Have 5 pairs of walking legs and 2 pairs of antennae.
b. Spiders and Scorpions	Have 4 pairs of walking legs and no antennae.
c. Centipedes	Have many pairs of walking legs but only one pair per segment and only one pair of antennae.
d. Millipedes	Have many pairs of walking legs, two pairs on each segment, and have one pair of antennae.
e. Insects	Have three pairs of walking legs and one pair of antennae. May or may not have wings.
Star-fish	Organisms adapted to a sedentary or non-motile existence. Have basically a star configuration. (starfish, sea cucumbers, sand dollars, and sea urchins)
Main Group II - Vertebrates:	Organisms having an endoskeleton, dorsal hollow nerve cord, digestive tract ventral to nerve cord and brain.
Common Name	
Jawless, Round Mouth Forms	Fish-like organisms having no jaws, no appendages and no bone. Gill breathing. Mouth is a round sucker and skeleton is cartilage. Heart has two chambers. (lampreys)
Sharks, Skates	Fish-like animals. Gill breathing, with upper and lower movable jaws. Have fins for appendages and skeleon is made entirely of cartilage. Two chambered heart.

True Fishes	Gill-breathing fish usually with dermal scales and having fins for appendages. Two-chambered heart. Skeleton made of bone.
Amphibians	Lung-breathing animals with two pairs of limbs. Have an external slimy skin. Three-chambered heart. (frogs, toads, newts, and salamanders)
Reptiles	Lung-breathing animals usually with 2 pairs of appendages. Have an outer dry scaly epidermal covering. Three-chambered heart, except alligator and crocodile with four chambers. (snakes, turtles, lizards, crocodiles, alligators)
Birds	Lung-breathing, two pairs of appendages, four heart chambers, and epidermal feathers. warm-blooded.
Mammals	Lung-breathing, two pairs of appendages, four heart chambers. Have hair and milk-secreting mammary glands.

The group of mammals contains 17 subgroups in which are placed animals like cattle, pigs, horses, elephants, cats, dogs, whales, rats, rabbits, shrews, bats, kangaroos, man, and a few others. The total classification for man is given below.

Phylum Vertebrate	all vertebrates
Class Mammalia	all mammals
Order Primate	apes, larsiers, monkeys, gorillas, man
Super Family - Hominoidea	apes, gorilla, man
Family Hominidae	man and gorilla
Genus - species - Homo sapiens	man only

Note: You are urged to study again from MOD 204 the three film loops that concern frog embryology; they will help you understand basic body plan.

MOD 297 Correlating Manipulatives for Multiplication and Division with Elementary Textbooks

This MOD is designed to allow you to explore the procedure used by an elementary textbook series in teaching multiplication and division to elementary children and to develop a plan for effectively utilizing manipulatives to enhance the process.

OBJECTIVES:

At the conclusion of this MOD you will present a written, detailed plan for the use of manipulatives for teaching multiplication and division and will demonstrate the use of the manipulatives.

INSTRUCTIONAL REFERENCES AND MATERIALS:

1. Kentucky Textbook Adoption List in Resource Center
2. Elementary textbooks in Resource Center
3. Manipulatives in Resource Center
4. References on use of manipulatives in Resource Center

PROCEDURES:

1. Identify a school system in Kentucky of your choice.
2. Determine a math series which has been adopted by that system.
3. Review the textbook series identified to discover the grade level where greatest emphasis is placed on multiplication and division.
4. Develop a thorough written plan for effective use of manipulatives for teaching multiplication and division at the identified grade level.
5. Be able to demonstrate the manipulatives utilized in your plan.

FINAL ASSESSMENT:

1. Present in good form the plan you have developed for using manipulatives for teaching multiplication and division along with any exercise sheets needed.
2. Be prepared to discuss your plan and demonstrate the use of the manipulatives.

University of Oklahoma
Science Education Center
Norman, Oklahoma 73019
June, 1979

In September, 1977, John W. Renner agreed to head a team to do a long-term evaluation of the Integrated Science Mathematics Education Project (ISMEP) beginning at Murray State College, Murray, Kentucky. The team consisted of Renner and two experienced graduate-student interviewers, S. Margaret Kennedy and Michael J. Renner. The evaluation was to consist of administering written texts and conducting personal interviews to determine levels of intellectual development as defined and illustrated by Jean Piaget. The data gathered in 1977 were supplied to the ISMEP in two reports; one report was dated September 8, 1977 and the other September 5, 1978. Those two reports constitute the baseline data for the current report.

The personal interviews with the students were conducted according to the interviewing protocols shown in Appendix A. Each interviewer conducted the interview with the same student in September, 1977, and May, 1979. M. Renner and Kennedy had been taught to administer the interview by J. Renner and data have shown that M. Renner and Kennedy conduct the interviews in a statistically equivalent manner. All interviews were conducted within two day periods in 1977 and 1979.

In addition to evaluating the intellectual development gains (or losses) made by the students at Murray State University, the evaluation team also agreed to do an evaluation of the mathematics compentencies gained (or lost) during period of the experiment. We have concluded that special problems exist in the mathematics competencies of the ISMEP students and those problems will be discussed in Part II of this report.

Part I of the report contains all the data relating to the intellectual developments gains (or losses) of the ISMEP students. Since some of those data deal with quantitative factors, some of those data are referred to again in Part II.

The design of this evaluation was control group, experimental group. The experimental group consisted of students from the ISMEP. The control group consisted of students selected from the general student body of Murray State College. The evaluators were not aware of the criteria used to select the control group (nor was there a need from them to know). Furthermore, the evaluators were not aware of which students belonged to the experimental group nor which to the control group until after all interviews had been conducted and all written work scored in May, 1979. The membership of each group was provided to J. Renner by the Director of the ISMEP by telephone on May 28, 1979.

In September, 1977, a total of 48 Murray State University students was interviewed. In May, 1979, 27 Murray State University students were interviewed. Of that group 15 were members of the experimental group and 12 were members of the control group. One additional student Lou Ann Kinard--a control group student--completed all the written evaluations but did not appear for the interview either in 1977 or 1979. She was therefore, dropped from the evaluation described in Part I.

The samples upon which the ISMEP is evaluated, therefore, are small. Any generalization made about the ISMEP have been made with that fact in mind. The sample size will not be mentioned again but the reader must be constantly aware of it. Furthermore, all statistical data reported were arrived at using statistical procedures which are proper for small-samples.

A second fact should be kept in mind when perusing the statistical data found in this report. Two groups were compared on several different competencies to see whether or not differences existed between them. In other words, the hypothesis that was statistically tested is the null--or no difference--hypothesis. To simplify data interpretation the null hypothesis is made and then tested for its probable truth or falsity. As in testing any hypothesis, there is a probability that the results obtained could have happened by chance. The statistical levels reported here give the probability that the results reported could have been attained by chance, given that the null hypothesis is true.

Two kinds of error can occur in the statistical testing of an hypothesis. There is a probability of rejecting a true hypothesis--Type I error-or accepting a false hypothesis--Type II error. The type of error most serious in testing any hypothesis depends, of course, upon the seriousness of the consequences of that type of error. Statistical levels are then adjusted to minimize the risk of making the type of error which is to be avoided.

Controlling the probability of making a Type I error is simple; a level of probability is set and all interpretations are made in terms of it. Common practice usually is to select the level of five percent as the level to use to avoid Type I error (although that "common practice" has something less than a sound scientific basis for its establishment).

The probability level (level of significance) necessary to avoid Type II error is not so simply determined. This report is not the place to discuss that procedure. The reader should be aware, however, that in the opinion of most persons engaged in statistical evaluations of curriculum work, avoiding Type II error is more important (in the opinion of J. Renner, much, much more important) than is avoiding Type I error. To reduce the probability of making a Type II error the level of significance for statistical tests is raised. Whereas a five percent level might be used to avoid making a Type I error, that level can be raised to the 10, 15, 20, or even 25 per cent level to avoid making a Type II error. The level used will depend upon the relative importance of making both kinds of errors because as the probability of making a Type II error decreases, the probability of making a Type I error increases.

Those operating a curriculum project must decide which type of error is most harmful to the final determination of the worth of the project and then make a decision about level of significance in terms of that decision. In the opinion of J. Renner making a Type I error in curriculum research generally results in the expenditure of unnecessary funds. But making a Type II error can result in discarding curricula that are beneficial to students and do considerable educational harm. For that reason, J. Renner has usually been willing in curriculum research to risk Type I error. That means that significance levels of 10, 15, or 20 percent are acceptable. The reader should keep that fact in mind when reading the interpretation of the statistical task included in this report.

PART I

The Interviews. The results of interviewing all 27 Murray State University students are found in Table I. A total interview score is found in the extreme right-hand colum in Table I. To arrive at that score point values must be attached to the Roman-numeral, letter designations. The point values attached are: III B = 4 points, III A = 3 points, II B = 2 points and II A = 1 point. The experimental-group students are designated in Table I with an asterisk.

The "Difference Score" column of Table II shows the gains and/or losses made by the students in both groups. The mean gain made by the control group was 1.42 and the mean gain made by the experimental group was 2.60. A computer-calculated statistical analysis of those data demonstrated that the difference in mean gain scores favored the experimental group at the 13.62 per cent level. If Type II error is the type to be avoided, that difference is significant. If Type I error is the type to be avoided that difference is not significant.

Consider the data in Table III. J. Renner believes there is a significant factor shown in those data. Notice how the lower scores in the pre-project interview

MURRAY STATE UNIVERSITY
MURRAY, KENTUCKY
May, 1979

TABLE I

POST-PROJECT INTERVIEW RESULTS

CONSERVATION of VOLUME	PROPORTIONAL REASONING	SEPARATION of VARIABLES	COMBINATIONAL REASONING	TOTAL SCORE
IIB	IIIB	IIIA	IIIA	12
IIA	IIB	IIIA	IIIA	9
IIIA	IIIA	IIIA	IIB	11
IIA	IIB	IIA	IIB	6
IIIA	IIIA	IIIA	IIB	11
IIIA	IIIB	IIB	IIB	11
IIA	IIB	IIA	IIB	6
IIIA	IIA	IIIB	IIIA	11
IIIA	IIB	IIIB	IIB	11
IIB	IIIA	IIIA	IIB	10
IIIA	IIIB	IIIA	IIB	12
IIIA	IIA	IIIA	IIB	9
IIB	IIIB	IIIA	IIB	11
IIIA	IIIA	IIIB	IIIB	14
IIIA	IIB	IIIA	IIB	10
IIIA	IIIA	IIIA	IIIA	12
IIIA	IIIB	IIIA	IIIA	13
IIIA	IIIA	IIIA	IIIA	12
IIIA	IIIA	IIIA	IIB	11
IIB	IIB	IIIA	IIB	9
IIIA	IIIA	IIIB	IIIA	13
IIB	IIB	IIB	IIB	8
IIIA	IIIA	IIIA	IIB	11
IIIA	IIIA	IIIA	IIIA	12
IIIA	IIB	IIB	IIB	9
IIIA	IIIA	IIIB	IIB	12
IIIA	IIB	IIIA	IIB	10

TABLE II

INTERVIEW DIFFERENCES SCORES -- PRE-PROJECT AND POST-PROJECT

NAME	PRE-PROJECT SCORE	POST-PROJECT SCORE	DIFFERENCE SCORE
EXPERIMENTAL GROUP			
	12	13	1
	10	11	1
	9	11	2
	7	11	4
	6	11	5
	6	10	4
	6	9	3
	12	11	-1
	9	12	3
	11	13	2
	4	11	7
	11	9	-2
	6	12	6
	9	12	3
	9	10	1
CONTROL GROUP			
	9	9	0
	11	11	0
	6	6	0
	7	6	-1
	10	12	2
	10	14	4
	9	10	1
	8	12	4
	9	13	4
	7	8	1
	8	11	3
	10	9	-1

TABLE III

INTELLECTUAL MOVEMENT IN THE EXPERIMENTAL GROUP VS. THE CONTROL GROUP

INTERVIEW SCORE	CONTROL GROUP		EXPERIMENTAL GROUP	
	Pre-Project Score	Post-Project Score	Pre-Project Score	Post-Project Score
1				
2				
3				
4			1	
5				
6	1	2	4	
7	2		1	
8	1	1		
9	3	2	4	2
10	3	1	1	2
11	1	2	2	6
12		2	2	3
13		1		2
14		1		
15				

remain in the post-project interview in the control group. Now notice the difference in the pre- and post- project scores in the experimental group. No score below 9 is found. Furthermore 11 scores (73 per cent) are found at the score of 11 and above in the experimental group while 6 scores (50 per cent) are found at the score of 11 and above in the control group.

Those data suggest that the experiences of the ISMEP group are effective in moving students out of the concrete thought period and into at least the period of transistion between concrete and formal thought. The experiences the control group had seem to do little to move them out of the concrete thought period. (As a rule-of-thumb, scores of eight and below probably represent concrete thought, scores of 9 and 10 probably represent thought in transistion between concrete and formal thought and scores of 11 and above probably represent reasonably formal thought.) The data in Table III suggest that students in the ISMEP have a better chance of entering the formal thought period than do those students in the general programs of Murray State University. In the complete interview, three of the tasks permitted a student to demonstrate the highest level of formal thought. Those tasks are (see Appendix A) the bending rods tasks, the balance beam task and the chemical combinations tasks. The bending rods tasks demands that the student be able to cognitively separate and control variables while solving a problem. The balance beam task requires proportional reasoning and the chemical combination task require the use of combinational logic.

A statistical analysis was made of the differences in the pre-project and post-project performances of the experimental and control groups on each task. That analysis revealed that there were no differences between the gains made by the experimental and control group in their ability to use combinational logic and proportioned reasoning. The experimental group, however, significantly outgained the control group on the ability to cognitively separate and control variables.

The level of statistical significance was 3.5 per cent--the most statistically significant finding in the entire evaluation.

Data from work done by Robert Fuller at the University of Nebraska suggests that the ability to separate and control variables must be developed before formal thought can fully develop. The fact that the experiences of the ISMEP group have led them to far exceed the general Murray State University students on the ability to separate and control variables suggests that students in the ISMEP group will leave the concrete period and enter at least the transitional-formal period more rapidly than the students in the control group. That suggestion is at least partially corroborated by the data shown in Table III.

The analysis of the interview data lead to at least one definite conclusion. The experiences the ISMEP students are having are leading them to develop the cognitive ability to separate and control variables far in excess of their Murray State peers.

The Group Embedded Figures Test.

When a student reacts to the apparatus used in conducting the interviews just discussed, perception of the apparatus and the problem to be solved using it must occur. If the student cannot perceive the problem to be solved with apparatus, the chances of the problem being solved seem to be decreased.

Data exist[1] that demonstrate that the cognitive characteristics of the Murray State University students that were being evaluated fall into the general area of perceptual field - dependence independence. The Group Embedded Figures Test [2] (GEFT) purports to discriminate between field dependent and field independent thinkers. In addition, the manual for this test states:

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[1] Philip K. Oltman, Evelyn Raskin and Herman A. Witkin, Group Embedded Figures Test Manual (Palo Alto, California: Consulting Psychological Press, 1971).

[2] Philip K. Oltman, Evelyn Raskin and Herman A. Witkin, Group Embedded Figures Test (Palo Alto, California: Consulting Psychological Press, 1971).

> . . . persons who have difficulty disembedding small figures from complex designs in the EFT tend to do less well in solving that class of problems which require isolating an essential element from the context in which it is presented and using it in a different context.[3]

The foregoing quotation strongly suggests that a person who does well on the EFT would also do well, on those college and life tasks which demand that decisions be made which reflect purpose for and understanding of a situation regardless of the background and setting in which that situation is found. In short, the GEFT suggests it can measure independent thinking which is a characteristic a college education should foster.

The GEFT was administered to the control and experimental group students at Murray State University. The results are shown in Table IV. A computer analysis of the data shown in Table IV demonstrated that the gains on the GEFT favored the experimental group. The experimental groups gain were statistically significantly better than the gains made by the control group at 7.8 per cent level. (Once again consider the type of error to be avoided when interpreting those results). Those data suggest that the ISMEP students are gaining more field independent thought than are the general students at Murray State University.

The Science Problems. The Science Education Center, University of Oklahoma, has done considerable work using science problems to measure intelluctual development.[4] The Murray State Students were asked to respond in writing to the four problems which have been found to be the best among all of those used. Those problems are included in Appendix B. The pre-project and post-project scores and the gains or losses of each student in both groups are shown in Table V.

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[3] Oltman, Raskin and Witkin, Manual, p. 6.

[4] John W. Renner, Evaluating Intellectual Development Using Written Responses to Selected Science Problems, Science Education Center, University of Oklahoma, 1977.

TABLE IV

PRE-PROJECT, POST-PROJECT GROUP EMBEDDED FIGURE TEST RESULTS

NAME	GROUP EMBEDDED FIGURES TEST		
EXPERIMENTAL GROUP	PRE-TEST	POST-TEST	DIFFERENCE
	14	17	3
	13	13	0
	6	8	2
	3	8	5
	4	9	5
	3	13	10
	5	7	2
	16	18	2
	6	7	1
	7	17	10
	9	13	4
	16	13	- 3
	14	17	3
	17	17	0
	10	9	1
CONTROL GROUP			
	16	16	0
	14	15	1
	6	11	5
	11	12	1
	10	13	3
	16	14	-2
	6	11	5
		14	
	15	18	3
	5	7	2
	11	9	-1
	10	7	-3

TABLE V

PRE-PROJECT AND POST-PROJECT SCORES ON THE SCIENCE PROBLEMS AND CHANGE DURING THE PROJECT

NAME	SCALE			SHADOWS			FROG			GERANIUM		
EXPERIMENTAL	PRE	POST	CHANGE	PRE	POST	CHANGE	PRE	POST	CHANGE	PRE	POST	CHANGE
	4	5	1	7	6	-1	2	2	0	4	4	0
	3	4	-1	7	7	0	2	7	5	4	3	-1
	2	3	1	2	2	0	2	2	0	3	4	1
	2	3	1	2	1	-1	2	1	-1	2	3	1
	2	2	0	2	2	0	1	2	1	3	3	0
	2	2	0	6	2	-4	4	2	-2	3	4	1
	2	2	0	2	2	0	3	2	-1	4	3	-1
	3	3	0	7	7	0	3	3	0	4	7	3
	4	2	-2	5	4	-1	3	2	-1	3	3	0
	3	4	1	6	5	-1	3	3	0	4	4	0
	2	3	1	5	1	-4	3	3	0	4	3	-1
	2	3	1	6	7	-1	3	3	0	4	5	1
	2	3	1	3	1	-2	2	2	0	4	4	0
	2	3	1	1	1	0	3	3	0	3	4	1
	3	4	1	1	1	0	3	1	-2	7	3	-4
CONTROL												
		1			6			1			1	
	3	3	0	1	7	6	3	3	0	4	4	0
		2			2			2			2	
	4	3	-1	2	2	0	3	3	0	3	3	0
	4	2	-2	6	1	-5	2	2	0	5	3	-2
	2	2	0	6	6	0	6	4	-2	3	3	0
	3	3	0	5	6	1	3	4	1	4	3	-1
	3	3	0	2	6	4	4	4	0	4	3	-1
	3	3	0	6	6	0	3	7	4	4	3	-1
	2	2	0	6	6	0	2	6	4	1	2	1
	2	3	1	6	6	0	1	4	3	4	4	0
	3	3	0	2	2	0	3	2	-1	3	2	-1

A computer analysis of the differences in the data shown in Table V reveal that the gains of the experimental group exceeded the control group as the Scale Problem at the 10.2 per cent level of significance. That problem is thought to measure the ability to use the cognitive trait of combinational logic. There were no differences on the two groups on that cognitive trait in the interviews.

The gains of the experimental group excelled that of the control group on the Geranuim problem but only at the 30 per cent level of significance. That problem is thought to measure the ability to measure the ability to separate and control variables. The gain by the experimental group far exceeded the gains by the control group on ability to separate and control variables on the interview.

Those data would suggest that using apparatus seem to assist the ability to measure the ability to separate and control variables. But using materials did not assist in measuring the ability to do combinational logic. The performances on the problem were better than with the apparatus. The only interpretation that can be made of these data is that some cognitive development is going on with the experimental group that does not seem to be taking place with the control group. That suggests the experiences provided by ISMEP are providing cognitive growth not provided by the general program of Murray State University but more data would be needed to isolate what exact cognitive growth is being provided by the ISMEP.

The last two science problems--the Shadows Problem and the Frog Problem both of which measure the ability to do proportional reasoning--introduce the special problem in the ISMEP which was referred to in the introduction of this report. A computer analysis of the difference data for the Shadows Problem found in Table V show that the control group outgained the experimental group at the 7.3 per cent level. That data analysis also shows that the control group outgained experimental group on the Frogs problem at the 20.5 per cent level. On the proportional reasoning portion of the interview--as was stated earlier--there was no difference between the gains made by the two groups on proportional reasoning. Actually, the computer analysis reported a statistical level of significance for the differences in gains as 50.0 per cent--pure chance. Clearly a problem exists in the mathematics portion of the ISMEP.

PART II

The experimental and control groups were evaluated on many different competencies in mathematics with special attention being given to their competency with the ratio concept. The ratio concept was singled out for special consideration because data supplied by Piaget and others indicate that the ability to use any ratio beyond two to one requires formal thought. The results of the pre-project and post-project evaluations of the entire samples are shown in Table VI and VII. Notice in those tables that the percentages of students missing each item are given.

Making any generalization from the data shown in Tables VI and VII is difficult. This seems to be only one constant trend. Data in Part I of this report demonstrated that students in the sample were moving into the formal thought period. The use of the ratio concept requires formal thought. The data in Tables VI and VII tend to show increased competence with the ratio concept. Item 12 in Table VI and all items in Table VII show an increased competence with the ratio concept.

Table VIII shows the pre-project and post-project mathematics test scores for each person in the experimental and control group. The differences between those score are also shown. A computer analysis of the differences in those scores found a significant difference in favor of the control group but at the 34 per cent level. Those data show this are no differences in the mathematical

TABLE VI

MATHEMATICAL COMPETENCIES OF THE PRE-PROJECT AND POST-PROJECT SAMPLES

Item's Position in the Test	Area of Mathematics being Evaluated	Concept being Evaluated	Percentage of Students Missing Each Item	
			Pre-Project Evaluation N = 45	Post-Project Evaluation N = 28
1	Arithmetic	Addition	0%	0%
2	Arithmetic	Subtraction	0%	0%
3	Arithmetic	Multiplication	2%	0%
4	Arithmetic	Division	37%	21%
5	Arithmetic	Addition of Fractions	11%	14%
6	Arithmetic	Multiplication of Fractions	24%	11%
7	Arithmetic	Square root	18%	8%
8	Scientific Notation	Add. & Subt. of Exponents	47%	54%
9	Arithmetic	Significant Figures	29%	25%
10	Arithmetic	Significant Figures	38%	39%
11	Arithmetic	Counting	2%	7%
12	Arithmetic	Percentage	69%	50%
13	Algebra	Rate	27%	25%
14	Algebra	Multiplication	33%	50%
15	Algebra	Solving for One Unkown	0%	0%
16	Algebra	Fraction Solving for 1 Unknown	24%	39%
17	Algebra	Simultaneous Equations	87%	86%
18	Geometry	Diameter	49%	29%
19	Geometry	Circumference	91%	86%
20	Geometry	Similar Triangles	98%	93%
21	Geometry	Area of a Triangle	93%	75%
22	Geometry	Pythagorean Theorem	87%	64%
23	Geometry	Degrees in a Triangle	62%	46%
24	Trigonometry	Functions	96%	100%
25	Trigonometry	Functions	91%	100%

TABLE VII

COMPETENCE OF THE PRE-PROJECT SAMPLE WITH THE RATIO CONCEPT

Item Number	Percentage of Students Missing Each Item	
	Pre-Project Evaluation N = 45	Post-Projection Evaluation N = 28
1	29%	18%
2	62%	54%
3	64%	46%
4	62%	39%

competencies of the groups. In other words the mathematical activities of the ISMEP were no more successful at teaching mathematics to future elementary school teachers than were the general activities of Murray State University students.

Since the evaluation of the mathematical competencies of the students with ISMEP was negative, the decision was made to explore the data further. The reader should keep in mind two factors which may have influenced the outcome of the mathematical experiences of the control group during the period September, 1977 throught May, 1979. Those data are needed before definite conclusions are drawn. Secondly, the instrument used to (See Appendix C) evaluate the mathematical competencies of the samples may not be valid to use in evaluating the mathematical experiences of those students in the samples.

To provide some insight into the differences between the mathematical competencies of the experimental and control groups, TAbles IX and X were prepared. Those Tables show the percentages of students[5] in each group that missed each item.

There seems to be no pattern in the data. Earlier the statement was made that the samples had increased their mathematical competencies during the treatment period but 60% of the experimental group missed Item 12, the computation of a simple percentage. Consider these facts about the experimental group:

1. 26.6% missed the simple division problem (No. 4)
2. 60.0% missed the percentage item (No. 12)
3. 33.3% missed the simple rate problem--again a ratio (No. 13)
4. 40% do not know what the diameter of a circle is (No. 18)

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[5] Notice that the size of the control group here is 13 rather than 12 as used in Part I. The student who did not complete the interviews (pre- and post-project) did complete the mathematics test. The decision was made to use those scores in this portion of the report.

TABLE VIII

PRE-PROJECT AND POST-PROJECT, MATHEMATICS TESTS AND DIFFERENCES

NAME	PRE-PROJECT	POST-PROJECT	DIFFERENCE
EXPERIMENTAL GROUP			
	14	17	3
	22	19	-3
	7	12	5
	11	13	2
	14	11	-3
	17	18	1
	7	12	5
	23	25	2
	14	11	-3
	20	22	2
	19	15	-4
	20	22	2
	13	16	3
	17	17	0
	15	17	2
CONTROL GROUP			
		13	
	15	24	9
		14	
	13	12	-1
	15	15	0
	21	22	1
	16	15	-1
	13	21	8
	20	21	1
	18	20	2
	21	20	-1
	11	15	4

TABLE IX

POST-PROJECT MATHEMATICAL COMPETENCIES OF THE SAMPLE

Item's Position in the Test	Area of Mathematics being Evaluated	Concept being Evaluated	Percentage of Students Missing Each Item EXPERIMENTAL GROUP N = 15	 CONTROL GROUP N = 13
1	Arithmetic	Addition	0	0
2	Arithmetic	Subtraction	0	0
3	Arithmetic	Multiplication	0	0
4	Arithmetic	Division	26.6	16.6
5	Arithmetic	Addition of Fractions	13.3	16.6
6	Arithmetic	Multiplication of Fractions	13.3	8.3
7	Arithmetic	Square root	6.6	8.3
8	Scientific Notation	Add. & Subt. of Exponents	66.5	41.6
9	Arithmetic	Significant Figures	13.3	41.6
10	Arithmetic	Significant Figures	33.3	41.6
11	Arithmetic	Counting	6.6	8.3
12	Arithmetic	Percentage	60.0	41.6
13	Algebra	Rate	33.3	16.6
14	Algebra	Multiplication	46.6	58.3
15	Algebra	Solving for One Unknown	0	0
16	Algebra	Fraction Solving for 1 Unknown	33.3	41.6
17	Algebra	Simultaneous Equations	93.3	83.3
18	Geometry	Diameter	40.0	16.6
19	Geometry	Circumference	86.6	83.3
20	Geometry	Similar Triangles	93.3	91.6
21	Geometry	Area of a Triangle	93.3	58.3
22	Geometry	Pythagorean Theorem	73.3	58.3
23	Geometry	Degrees in a Triangle	40.0	50.0
24	Trigonometry	Functions	100.0	100.0
25	Trigonometry	Functions	100.0	100.0

TABLE XI

COMPETENCE OF THE SAMPLE WITH THE RATION CONCEPT

Item Number	Percentage of Students Missing Each Item	
	Experimental Group N = 15	Control Group N = 13
1	13.3	25
2	66.6	25
3	66.6	50
4	40	41.6

Those seem to be glaring mathematical deficiences in the experimental group. Furthermore, Items 19 through 23 show that the geometry the students have been exposed to throughout their entire educational career has not been effective; 86.6 per cent cannot find the circumference of a circle when given the value for the circle's radius and the value of π (3.14). Yet these people are expected to teach some simple geometry in the elementary school. The fact that they and their students are at an extreme disadvantage is obvious.

What could be done to help relieve the situation? The ISMEP is built upon the hypothesis that interaction with materials improves student opportunities for learning science content and learning how to learn. The fact that the ISMEP students excelled the control group students on some measure of intellectual development suggests that perhaps the basic ISMEP hypothesis may be true.

Assume that the basic ISMEP hypothesis is true. Mathematics beyond counting, serial ordering, addition and subtraction, requires, at least, borderline formal operational thought. Suppose that the students in the ISMEP were first given an extensive instruction with the materials of science--perhaps as much as a year--before instruction in mathematics was started. Just possibly the intensive instruction with the materials of science will intellectually move the students near enough toward the formal thought stage that instruction in mathematics would be profitable. The conclusion must be drawn from the data presented here that the mathematics instruction in the ISMEP is not profitable. Please accept the above hypothesized plan as just that--an hypothesis.